Alterations of the electrocardiographic parameters in relation to circulating electrolytes and cardiac enzymes during different productive states of high producing Holstein dairy cows

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Abstract:

BACKGROUND: Dairy cows undergo physiological changes during pregnancy and lactation and cardiovascular system may alter during these periods. **OBJECTIVES:** Understanding the physiological effects of production periods of dairy cows on heart electrical activities can aid in better monitoring the cardiovascular system in these animals. **METHODS:** Five multiparous Holstein dairy cows were studied from early lactation to close-up dry periods. Electrocardiogram recordings and blood samplings were performed from each cow at their different productive states. Sera were separated and the concentrations of sodium, potassium, chloride, calcium, magnesium, phosphorus, aspartate aminotransferase, alanine transaminase and lactate dehydrogenase were evaluated in all specimens. **RESULTS:** There were no significant changing patterns in P, Q, S and T amplitude from early lactation to close-up dry periods ($p>0.05$); however, the R amplitude was significantly increased from early to late lactation and then decreased to close-up dry period, subsequently ($p<0.05$). P wave had the longest and Q wave had the shortest durations during different productive states. There were no significant changing patterns in PR, QT and ST intervals from early lactation to close-up dry periods ($p>0.05$) but RR interval in dry periods was significantly longer than lactating ones. Serum concentrations of calcium, phosphorus, sodium, chloride, potassium, aspartate aminotransferase, alanine transaminase and lactate dehydrogenase were decreased significantly from lactating cows to non-lactating ones ($p<0.05$). **CONCLUSIONS:** The heart electrical activities of dairy cows at each production period were different from another one. The differences among serum electrolyte levels may affect the electrocardiographic findings at each production period which may alter the production and conduction of cardiac electrical impulses. Furthermore, the cardiac activities in different production periods could have a significant impact on the levels of circulating cardiac enzymes.

Introduction

Dairy cows undergo physiological changes during pregnancy and lactation (Tanritanir et al., 2009). Each state has characteristics which are different from those of others.

Two to three weeks before parturition, a phase of catabolism starts to prepare the cow for parturition and the initiation of lactation. Immediately after the calving, they commence lactogenesis at the high levels which is associated with decreasing the body condition score (BCS), subsequently (Wathes et al., 2009). The last period of the production year is a phase of anabolism where the emphasis is put on increased weight gain as a long term preparation for the next lactation. Pregnancy and fetal growth at this period can also influence the physiological pathways of dairy cows (Piccione et al., 2012). Information regarding the physiological alterations in each productive period can lead to better manage the high producing dairy cows (Duffield, 2000).

Cardiovascular system has a key role in reproductive performance, pregnancy and lactogenesis. We hypothesized that this system may alter during physiological alteration of dairy cows from early lactation to close-up dry periods. Hence, we used the electrocardiography to evaluate the cardiac electrical activities of dairy cows at different productive states. The electrocardiogram (ECG) is a noninvasive and inexpensive diagnostic technique which measures and evaluates the heart electrical activities. Some of the cardiac problems can be detected by clinical evaluation such as auscultation but the executive details of cardiac electrical performance should be detected by using ECG (Radostits et al., 2007; Jafari Dehkordi et al., 2014a,b). The majority of conduction disturbances can be detected on clinical examination (Radostits et al., 2007) but several researchers recorded the cardiac abnormalities of the large animals which have not been detected by clinical investigations (Pourjafar et al., 2012; Chalmeh et al., 2014; Chalmeh, 2015; Trenk et al., 2015). Alterations of the heart electrical activities in large animals include physiological and pathological abnormalities (Radostits et al., 2007; Yoshida et al., 2015) in which physiological variations in normal animals may be detected electrocardiographically due to autonomic influence, primary myocardial disease and acid-base and electrolyte imbalances (Radostits et al., 2007); therefore, we also assessed the serum electrolytes and cardiac enzymes following the alterations of physiological states of dairy cows to better understand the heart electrical activities. Based on the author's knowledge, there are several studies on bovine ECGs alone without the interrelationships with electrolyte and cardiac enzymes (Deroth, 1980; Pourjafar et al., 2012; Chalmeh et al., 2014; Chalmeh, 2015). However, information regarding the electrocardiographic alterations during the different physiological periods of the same dairy cows is lacking. Therefore, the current research was designed to present the alterations of the electrocardiographic parameters in relation to circulating electrolytes and cardiac enzymes during different production states of high producing Holstein dairy cows.

Materials and Methods

Animals: The present experimental study was carried out in 2015 on 5 multiparous Holstein dairy cows from a high producing industrial dairy farm around Shiraz, in the southwest of Iran. The animals had 3 and/ or 4 times parturition. Cows were housed in open-shed barns with free access to water and shade. The total mixed rations were formulated and prepared for all animals at different productive states according to

National Research Council (NRC) requirements (Table 1). In this farm, a dry period of 60 days has been considered. Milk production was about 10,000 kg per year per head, an average of 3.6 of milk fat %, and 3.3 of milk protein %. All the animals were clinically healthy, had no history of debilitating disease and clinical signs of heart diseases (edema, jugular distension or pulsation and cardiac murmurs), coughing, exercise intolerance, and were free from internal and external parasites due to routine antiparasitic programs at this farm. BCS was estimated based on 0-5 system. We selected these 5 cows at their far-off dry period (281.9 ± 5.4 days after calving, 228.4 ± 8.6 days of pregnancy, with 3.5 ± 0.25 BCS) and studied them from this period to close-up dry periods (312.1 ± 8.3 days after calving, 255.6 ± 6.3 days of pregnancy, with 3.5 ± 0.25 BCS), early (30.2 ± 5.7 days after calving, with 3.25 ± 0.25 BCS), mid (108.1 ± 8.4 days after calving, with 3.25 ± 0.25 BCS) and late lactations (184.5 ± 5.7 days after calving, with 3.5 ± 0.25 BCS).

Electrocardiographic studies: The ECGs were recorded at 07:00 AM, 3 h after morning meal, on a bipolar base apex lead, using limb lead I (Fig. 1). Animals were kept standing without any sedation and minimum restraint. When animals became calm (decrease in panting behavior and muscle tremors), the ECGs were recorded, using alligator-type electrodes which were attached to skin after cleaning it with ethanol and applying electrocardiographic jelly to improve skin contact. The positive electrode (left arm) was placed over cardiac apex on the 5th left intercostal space at the level of the elbow, the negative electrode (right arm) was placed on the left jugular furrow at the top of heart base, and the neutral electrode was placed on the dorsal spine or another site away from the heart (Radostits et al., 2007). All ECGs were obtained in a single channel electrocardiographic machine (Kenz-line EKG 110, Suzuken Co., Ltd., Japan) with paper speed of 25 mm/sec and calibration of 10 mm/1 mV. The precision of duration was 0.02 s, the amplitude 0.05 mV.

Blood sampling and biochemical assays: Blood sampling was performed after ECG was recorded from each animal via middle coccygeal vein. Immediately after blood collections, sera were separated by centrifugation for 10 min at 3000g and stored at -22 °C until assayed. Serum chloride and phosphorus were analyzed using routine biochemical procedures (Burtis and Ashwood, 1994). The serum concentrations of sodium and potassium were measured by the flame photometry (Flame Photometer, FLM, Ontario, Canada). The samples were also analyzed for magnesium and calcium by atomic absorption spectroscopy (Shimadzo AA-670, Japan). Values of serum aspartate aminotransferase (AST), alanine transaminase (ALT) and lactate dehydrogenase (LDH) were measured with Integra 800 auto-analyzer (Roche-Cobes, Switzerland).

Statistical analyses: Data were expressed as mean ± standard deviation (SD). Statistical analyses were performed using one-way ANOVA with LSD post-hoc test to compare mean concentrations of different electrocardiographic parameters and serological factors among different groups. Repeated measures ANOVA was also used to study the changes in pattern of different electrocardiographic parameters and serum electrolytes and enzymes during the productive states of the cows, using SPSS

Table 1. The basic nutrient content of rations in different physiological states of studied high producing Holstein dairy cows. DMI: dry matter intake; NEL: net energy lactation; CP: crude protein; RDP: rumen degradable protein; RUP: rumen undegraded protein; MP: metabolizable protein; ME: metabolizable energy; NDF: neutral detergent fiber; ADF: acid detergent fiber; NFC: non-fiber carbohydrate. Trace mineral added to ration (expressed as ppm): cobalt: 0.11; copper 10-18; iodine: 0.3-0.4; iron: 13-130; manganese: 14-24; selenium: 0.30 and zinc: 22-70.

Nutrient	Early lactation	Mid lactation	Late lactation	Far-off dry	Close-up dry
DMI (kg/day)	30	24	20	14	10
NEL (Mcal/kg)	1.61	1.47	1.36	1.32	1.43
Fat (%)	7	6	4	3	4
CP (%)	16.7	15.2	14.1	9.9	12.4
RDP (%)	9.8	9.7	9.5	7.7	9.6
RUP (%)	6.9	5.5	4.6	2.2	2.8
MP (%)	11.6	10.2	9.2	6.0	8.0
NDF (%)	28	30	32	40	35
ADF (%)	19	21	24	30	25
NFC (%)	38	35	32	30	34
Calcium (%)	0.60	0.61	0.62	0.44	0.48
Phosphorous (%)	0.38	0.35	0.32	0.22	0.26
Magnesium (%)	0.21	0.19	0.18	0.11	0.40
Chlorine (%)	0.29	0.26	0.24	0.13	0.20
Sodium (%)	0.22	0.23	0.22	0.10	0.14
Potassium (%)	1.07	1.04	1.00	0.51	0.62
Sulfur (%)	0.20	0.20	0.20	0.20	0.20
Vitamin A (IU/day)	75,000	75,000	75,000	80,300	83,270
Vitamin D (IU/day)	21,000	21,000	21,000	21,900	22,700
Vitamin E (IU/day)	545	545	545	1,168	1,200

software (SPSS for Windows, version 11.5, SPSS Inc, Chicago, Illinois). The level of significance was set at $p<0.05$.

Results

Electrocardiographic parameters and circulating electrolytes and cardiac enzymes (mean±SD) of high producing Holstein dairy cows at their different productive states are presented in Table 2. Furthermore, the changing patterns of the electrocardiographic parameters and serum electrolytes and cardiac enzymes during different productive states of studied high producing Holstein dairy cows are drawn in Fig. 2 and 3.

Based on the findings, there were no significant changing patterns in P, Q, S and T amplitude from early lactation to close-up dry periods ($p>0.05$; Fig. 2); However, the R amplitude was significantly increased from early to late lactation and then decreased to close-up dry period, subsequently ($p<0.05$). R wave had the highest and S wave had the lowest amplitude at all studied productive states (Fig. 2). There were no significant changing patterns about electrocardiographic durations from early lactation to close-up dry periods ($p>0.05$; Fig. 2). P wave had the longest and Q wave had the shortest durations during different productive states. There were no significant changing patterns in PR, QT and ST intervals from early lactation to close-up dry periods ($p>0.05$; Fig. 2) but RR interval in dry periods was significantly longer than lactating ones. Serum concentrations of calcium and

Table 2. Electrocardiographic parameters and circulating electrolytes and cardiac enzymes (mean ± SD) of high producing Holstein dairy cows (n=5) at their different productive states. [a,b,c] Different letters indicate significant difference among groups at similar parameter ($p<0.05$).

Parameters	Early lactation	Mid lactation	Late lactation	Far-off dry	Close-up dry
P-amplitude (mV)	0.18±0.02	0.17±0.04	0.16±0.04	0.13±0.03	0.15±0.03
Q-amplitude (mV)	0.16±0.12	0.15±0.09	0.10±0.05	0.12±0.07	0.12±0.09
R-amplitude (mV)	0.87±0.16[a]	0.99±0.27[a]	1.07±0.13[a]	0.74±0.18[b]	0.70±0.10[b]
S-amplitude (mV)	0.02±0.03	0.05±0.04	0.00±0.01	0.02±0.02	0.03±0.04
T-amplitude (mV)	0.40±0.08[a]	0.40±0.17[a]	0.44±0.13[a]	0.28±0.09[b]	0.25±0.05[b]
P-duration (Sec)	0.09±0.01	0.10±0.01	0.10±0.01	0.10±0.01	0.09±0.01
Q-duration (Sec)	0.02±0.01	0.02±0.01	0.02±0.01	0.02±0.01	0.02±0.01
R-duration (Sec)	0.06±0.01	0.06±0.01	0.06±0.01	0.05±0.01	0.05±0.01
S-duration (Sec)	0.02±0.01	0.03±0.02	0.03±0.01	0.03±0.02	0.03±0.02
T-duration (Sec)	0.07±0.01	0.07±0.01	0.07±0.01	0.07±0.02	0.06±0.01
PR-interval (Sec)	0.24±0.02	0.22±0.01	0.20±0.02	0.22±0.01	0.22±0.01
RR-interval (Sec)	0.78±0.02[a]	0.72±0.06[a]	0.69±0.06[a]	1.16±0.16[b]	0.93±0.18[b]
QT-interval (Sec)	0.40±0.01	0.37±0.03	0.36±0.04	0.45±0.03	0.41±0.05
ST-interval (Sec)	0.31±0.03	0.25±0.03	0.29±0.04	0.33±0.05	0.30±0.03
Calcium (mg/dL)	9.60±0.65[a]	9.48±0.21[a]	9.25±0.48[a]	9.84±0.38[b]	4.72±1.47[b]
Magnesium (mg/dL)	2.64±0.25[a]	2.42±0.16[a]	2.34±0.22[a]	2.30±0.18[b]	1.20±0.48[b]
Phosphorous (mg/dL)	7.17±1.03[a]	5.87±0.37[a]	7.04±0.89[a]	5.37±1.13[a]	3.52±1.30[b]
Sodium (mmol/L)	143.85±7.69[a]	142.71±7.95[a]	149.28±9.92[a]	141.28±0.95[a]	58.42±30.28[b]
Chloride (mmol/L)	105.57±3.20[a]	103.14±1.77[a]	102.00±1.63[a]	106.57±1.39[a]	55.92±18.14[b]
Potassium (mmol/L)	4.70±0.25[a]	4.60±0.21[a]	4.74±0.88[a]	4.70±0.24[a]	2.12±1.09[b]
AST (U/L)	75.71±14.20[a]	73.57±9.34[a]	77.42±10.96[a]	64.00±17.45[b]	28.28±10.98[c]
ALT (U/L)	24.42±5.12[a]	29.28±3.49[a]	31.28±8.82[a]	18.71±4.02[b]	10.85±6.01[c]
LDH (U/L)	1751.42±121.85[a]	1800.00±178.79[a]	1894.28±273.12[a]	1460.00±215.48[b]	530.85±231.60[c]

phosphorus were decreased significantly from lactating cows to non-lactating ones ($p<0.05$; Fig. 3). The levels of these electrolytes in dry cows were significantly lower than lactating groups and their concentrations were detected at the lowest levels in close-up dry period, significantly ($p<0.05$; Table 2). The significant decreasing patterns of sodium, chloride and potassium were detected from early lactation to close-up dry period and their concentrations in close-up dry group were significantly lower than other groups ($p<0.05$; Fig. 3; Table 2). The circulating levels of AST, ALT and LDH in close-up dry period were significantly lower than other periods and there were significant decreasing patterns of them from early lactation to close-up dry cows ($p<0.05$; Fig. 3; Table 2).

Discussion

There were differences among electrocardiographic amplitudes, durations and intervals at several productive states of high producing Holstein dairy cows. The higher amplitudes can draw the following powerful cardiac contractions and thin thorax (Deroth, 1980). In this study, lactating cows had lower BCS in comparison with dry ones; furthermore, the demands of the mammary glands for more blood supply for lactogenesis may increase the cardiac contractility in lactating periods, hence, the amplitudes in early, mid and late lactations were significantly recorded higher than far-

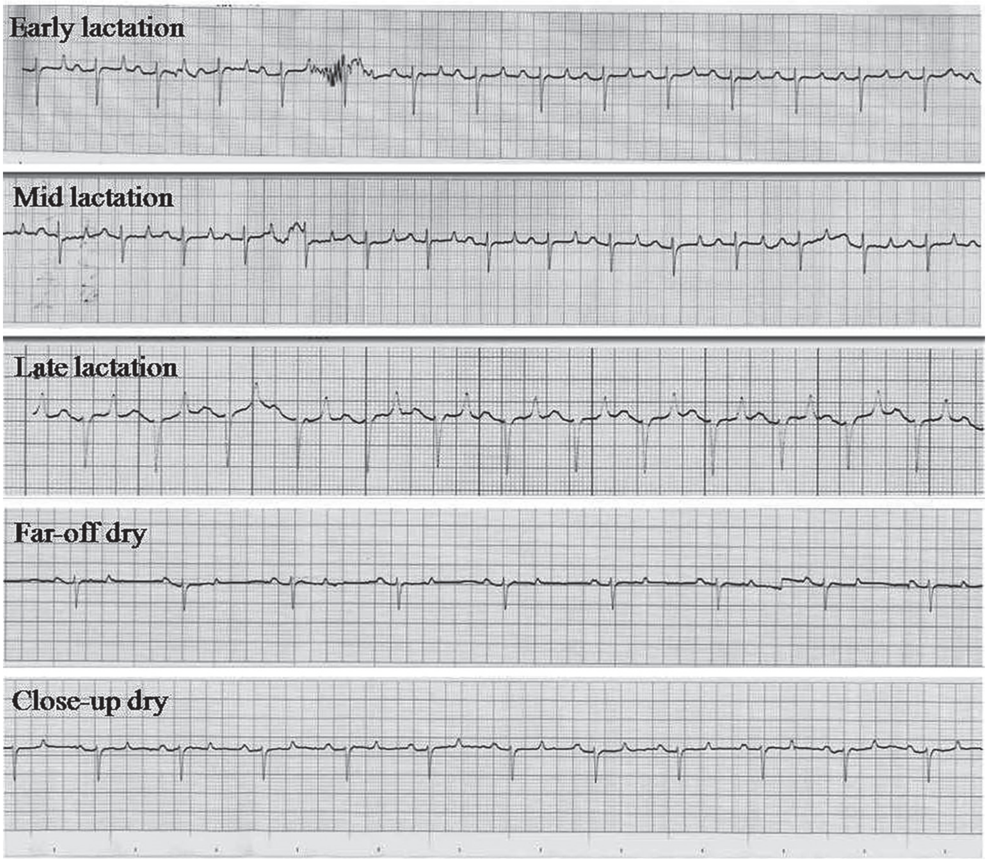

Figure 1. Normal electrocardiograms tracing from an adult multiparous high producing Holstein dairy cow at her different productive states from early lactation to close-up dry periods (base apex lead, paper speed 25 mm/sec, sensitivity 10 mm/mV).

off and close-up dry periods. Increasing the BCS and fattening the cows can act as the insulation and electrical impulses recorded with lower amplitudes (Too et al., 1966). The cardiac contractile activities in lactating cows are higher than non-lactating ones and these powerful contractions may cause the higher recorded amplitudes. P wave had the longest duration at all productive states. This wave was recorded along with the atrial depolarization and before atrial contraction commencement (Radostits et al., 2007).

Transferring the electrical impulses from sinoatrial to atriaoventricular node delay is due to the large atrium of dairy cattle, which records the long P wave in comparison with other waves (Rezakhani et al., 2004). P wave duration in mid lactating cows was longer than other groups, non-significantly. It may be suggested that this finding may be due to physiological alterations of cardiac musculature in order to compensate the lactating demands of dairy cows at mid lactation period. There were no significant changing patterns in PR, QT and ST intervals from early lactation to close-up dry periods; however, RR interval in lactating cows was significantly lower than non-lactating ones. RR interval reveals the distance between two heart rates and increasing this interval shows the low heart rate (Radostits et al., 2007). Transitioning the cows from lactating to non-lactating periods can cause the lower mammary gland demands to blood

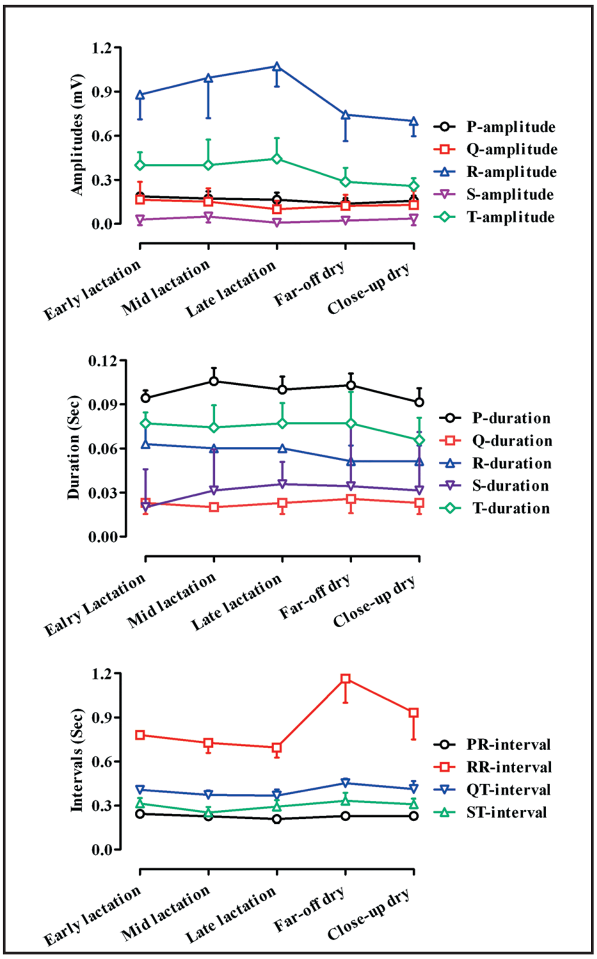

Figure 2. Changing pattern of electrocardiographic amplitudes, durations and intervals (mean ± SD) from early lactation to close-up dry periods of 5 adult multiparous high producing Holstein dairy cows.

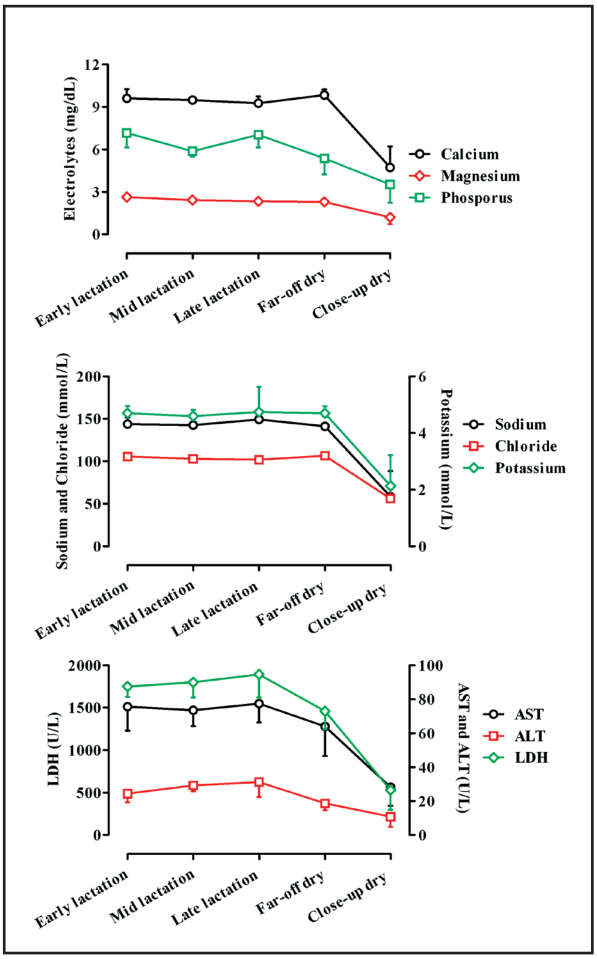

Figure 3. Changing pattern of serum electrolytes and cardiac enzymes (mean ± SD) from early lactation to close-up dry periods of 5 adult multiparous high producing Holstein dairy cows.

in order for lactogenesis; hence, the heart rate reduces in dry periods. RR interval was decreased at the close-up dry cows which may be due to the needs of gravid uterus and lactogenesis commencement. Decreasing the RR interval is equal to increasing the heart rate. Cardiac output follows from the heart rate and increasing the heart rate can cause the high cardiac output (Radostits et al., 2007).

Resolving the fetal growth and lactogenesis demands in close-up dry cows could be done due to increasing the cardiac output which followed from higher heart rate and lower RR interval in this group in comparison with far-off dry cows. Serum concentrations of calcium and phosphorus in non-lactating groups were lower than lactating cows and their levels at close-up dry period were significantly lower than others. Comparing the low calcium and phosphorus amount in the ration of non-lactating cows (Table 1), and the presence of sub-clinical hypocalcemia in these animals (Radostits et al., 2007), may explain the lower circulating levels of calcium and phosphorus in dry period.

Failure to secrete sufficient levels of parathyroid hormone was the primary defect in cows with hypocalcemia. While it is accepted that the calcium homeostatic mechanisms regulated by parathyroid hormone fail to maintain normal blood calcium concentrations resulting in severe hypocalcemia, the nature of this endocrine defect is not well understood. It was also once thought that calcitonin, a hormone which inhibits bone calcium resorption was a cause of milk fever but this has not been demonstrated in cows with clinical hypocalcemia. Systemic acidification induced by anionic supplementation affects the function of the parathyroid hormone. The major effect of systemic acidification is to cause an increased response to parathyroid hormone which results in increased retention of calcium and enhanced mobilization of calcium from bone. A total DCAD in the range of -100 to -200 mEq/kg feed DM is effective in controlling hypocalcemia (Radostits et al., 2007).

Serum concentrations of sodium, chloride and potassium in close-up dry cows were significantly lower than other groups. Dairy cows receive electrolytes needs from their food intake. In this study, sodium, chloride and potassium amounts in the balanced ration of dry cows were lower than lactating ones. Furthermore, based on the large size of gravid uterus, the capacity of gasterointestinal tract to food intake is reduced, which causes the reduction of received electrolytes to the cow at close-up dry period. Due to the distribution of the main intra and extracellular electrolytes such as sodium, potassium and chloride, the interior of the cardiac cells is more negative than the exterior. In myocardial cells, the interior is maintained more negative than the exterior by the extrusion of 3 sodium ions for every 2 potassium ions pumped in by the sodium/potassium ATPase pump. Movement of electrolytes across the impermeable cell membrane is through a number of channels (sodium and potassium channels, e.g.) that permit or prevent the movement of ions depending upon transmembrane voltage. Whereas calcium is the main electrolyte responsible for pacemaker cell depolarization, sodium is the main electrolyte responsible for depolarization of myocardial cells and cells dedicated to conduction of impulses (Fisch, 1984). The lower potassium concentrations were detected at dry periods. In humans, hypokalaemia is known to produce typical changes in the T wave, in particular decreased amplitude and the appearance of a U wave (Surawicz et al., 1957). Similar changes have been observed in hypokalaemic dogs (Felkai, 1985). In Hanton et al.'s (2007) study, hypokalaemia was also associated with decreasing amplitude of the T wave and with morphological changes in tracings recorded in CV5RL. The results of the present study showed that there were no significant changing patterns in all amplitudes except R amplitude which was significantly decreased at close-up dry period ($p<0.05$).

Potassium plays a key role in electrophysiological phenomena and, in particular, in the repolarization of the ventricular cells (Gadsby et al., 1995). Hypokalaemia increases the duration of cardiac action potential and, consequently, prolongs QT interval. The inhibition of cardiac repolarization associated with a decrease in extracellular potassium is assumed to be related to faster inactivation of potassium channels responsible for delayed potassium outflow and consequent inhibition of repolarization currents (Yang et al., 1997). The PR interval can be prolonged along with an increase in the amplitude of the P wave (Drighil et al., 2007). In the present research, the RR interval was increased significantly at dry periods when potassium levels in these periods were significantly lower than lactating ones

($p<0.05$). Akita et al. (1998) demonstrated that the ECG changes that are induced by hypokalemia in the rat, including suppression of conduction in most parts of the heart, prolong the QT interval, and decrease the amplitude of all waves except P waves. A prolonged QT interval is also a typical ECG manifestation of hypokalemia. A low extracellular potassium concentration produced a prolonged action potential and increased the time of diastolic depolarization (Gettes and Surawicz, 1968). In humans, the cardiac effect of hypokalaemia is well documented. Decreases in potassium plasma levels might occur in different pathological states and may be produced by a number of drugs (Cohen et al., 2002). Hypokalaemia could have a major effect on cardiac repolarization and ECG durations (Yelamanchi et al., 2001). Hyponatraemia would have a QT prolongation effect similar to that of hypokalaemia (Yelamanchi et al., 2001). However, sodium produces electrophysiogical abnormalities only at a concentration well outside the physiological range (Surawicz, 1980). Theoretically, reduction of the extra cellular concentration of sodium should slow cardiac pacemaker activity. In animal models, wide QRS complexes, either through hyperkalemia or quinidine administration have been documented (Surawicz, 1980). Hyponatremia plays as a role in the pathogenesis of the cardiac conduction defect. In the present study, sodium concentrations were decreased from lactating to non-lactating periods, significantly, which may be responsible for some electrocardiographic alterations at these periods.

Based on several researches, the solubility and absorption of Mg in acid solutions is higher than other ones. For instance, Ben-Ghedalia et al. (1975) observed that the solubility of Mg within the small intestine is maximal between the pylorus and 7 meters after the pylorus within the pH range from 2.6 to 7.02 and decreased according to the rise in pH. This also appears to be the case with caecal digesta and rumen contents in which a decrease in pH has been associated with an increase in Mg solubility, reflecting the greater solubility of Mg in acid solutions (Grace et al., 1977; Hom and Smith, 1978; Dalley et al., 1997). Acidification of the rumen contents occurs with fermentation and degradation of organic matter and this effect could enhance Mg solubility and therefore availability for absorption (Ben-Ghedalia et al., 1975; Hom and Smith, 1978). The major change in solubility observed in vitro occurs around pH 5.5-6.0 and pH 6.5-7.0 for ruminal and caecal samples, respectively (Dalley et al., 1997). It may explain the low level of serum Mg of close up cows, despite of 0.4% in their DMI.

The circulating levels of cardiac enzymes in dry cows were significantly lower than lactating ones and their concentrations in close-up were lower than far-off dry group, significantly. Based on the high myocardial activity of dairy cows at their lactating periods, the high serum levels of cardiac enzymes were detected in lactating groups. However, according to clinical healthiness of the studied cows at all production cycles, it may be suggested that the elevation of cardiac enzymes at lactating periods was physiologic and not related to myocardial injuries. LDH activity rises slowly after myocardial infarction (Ohman et al., 1982). Determinations of LDH activity have been used diagnostically to determine whether acute myocardial infarction occurred in the days before a patient was evaluated (Adams et al., 1993). In the diagnosis of acute myocardial infarction, the measurement of elevated levels of LDH is well known (Jaffe et al., 1984). Measurements of AST and ALT activities are common laboratory tests, usually requested as an aid for diagnosis and surveillance of cardiac problems and both AST and ALT activities rise after an acute myocardial infarction (Ohman et al., 1982). AST lacks organ specificity but is present in skeletal muscle, cardiac muscle and liver of large animals; the pathological changes in these organs elevate the activity of AST in the blood (Kaneko et al., 2008). AST is also an intracellular enzyme involved in amino acid and carbohydrate metabolism, and its elevated levels show the damage in the organ whose cells are rich in this enzyme such as the heart (Aziz and Mahboob, 2010). In contrast, elevation in ALT levels is widely viewed as a specific indicator of liver necrosis and cardiac injuries. Elevated ALT activity is associated with the high risk of chronic heart disease. Both AST and ALT activities rise after an acute myocardial infarction (Ohman et al., 1982).

In conclusion, it could be stated that the heart electrical activities of dairy cows at each production period were different from other ones which may be related to lactogenesis, pregnancy and fetal growth. The differences among serum electrolyte levels may affect the electrocardiographic findings at each production period which could alter the production and conduction of cardiac electrical impulses. Furthermore, the cardiac activities in different production periods could have a significant impact on the levels of circulating cardiac enzymes. However, based on the clinical healthiness of studied cows, all of the electrocardiographic, serum electrolytes and enzymes alterations may be considered as physiological events. Furthermore, these findings could be used as guidelines to evaluate the cardiac electrical activities of high producing Holstein dairy cows at different production states.

Conflict of interest: The authors declare that there is no conflict of interest.

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تغییرات فراسنجه‌های الکتروکاردیوگرافیک در ارتباط با الکترولیت‌های سرمی و آنزیم‌های قلبی در خلال دوره‌های مختلف تولیدی گاوهای شیری هلشتاین پرتولید

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چکیده

زمینه مطالعه: گاوهای شیری تغییرات فیزیولوژیکی را در خلال دوره‌های مختلف شیردهی و آبستنی متحمل می‌شوند و متعاقباً ممکن است سیستم قلبی عروقی، در این دوره‌ها دچار تغییر شود. **هدف:** آگاهی از اثرات فیزیولوژیک دوره‌های تولیدی گاوهای شیری بر فعالیت الکتریکی قلب می‌تواند کمک شایان توجهی در پایش بهتر سیستم قلبی عروقی در این حیوانات ارائه کند. **روش کار:** تعداد ۵ رأس گاو شیری هلشتاین چندشکم زاییده از دوره ابتدای شیردهی تا انتهای خشکی مورد مطالعه قرار گرفتند. ثبت الکتروکاردیوگرام و اخذ خون از هر گاو در دوره‌های مختلف تولیدی انجام شد. سرم‌ها جداسازی و غلظت سرمی سدیم، کلر، پتاسیم، کلسیم، منیزیم، فسفر، آسپارتات آمینوترانسفراز، آلانین ترانسفراز و لاکتات دهیدروژناز در تمامی نمونه‌ها مورد ارزیابی قرار گرفت. **نتایج:** الگوی تغییرات معنی‌داری در ارتفاع امواج P، Q، S و T از ابتدای شیردهی تا انتهای خشکی مشاهده نشد (p>۰/۰۵)؛ اما ارتفاع موج R از ابتدا تا انتهای شیردهی به طور معنی‌داری افزایش و سپس تا انتهای خشکی کاهش یافت (p<۰/۰۵). در تمام دوره‌ها موج P طولانی‌ترین و موج Q کوتاه‌ترین طول را دارا بودند. الگوی تغییرات معنی‌داری در فواصل PR، QT و ST از ابتدای شیردهی تا انتهای خشکی وجود نداشت(p>۰/۰۵)؛ اما فاصله RR در گاوهای خشک به طور معنی‌داری کمتر از گاوهای شیرده بود. غلظت سرمی سدیم، کلر، پتاسیم، کلسیم، منیزیم، فسفر، آسپارتات آمینوترانسفراز، آلانین ترانسفراز و لاکتات دهیدروژناز به طور معنی‌داری از گاوهای شیرده به گاوهای غیرشیرده کاهش یافت (p<۰/۰۵). **نتیجه‌گیری نهایی:** فعالیت الکتریکی قلب در گاوهای شیری در هر دوره متفاوت از سایر دوره‌ها بود. تفاوت بین مقادیر سرمی داده‌ها احتمالاً بر تغییرات یافته‌های الکتروکاردیوگرافیک موثر است و می‌تواند بر ایجاد و هدایت ایمپالس الکتریکی موثر باشد. علاوه براین، فعالیت‌های قلبی در دوره‌های مختلف تولیدی گاوها می‌تواند تأثیرات معنی‌داری بر روی میزان آنزیم‌های قلبی داشته باشد.

واژه های کلیدی: آنزیم‌های قلبی، گاوهای شیری، الکترولیت‌ها، الکتروکاردیوگرافی، دوره‌های فیزیولوژیک

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