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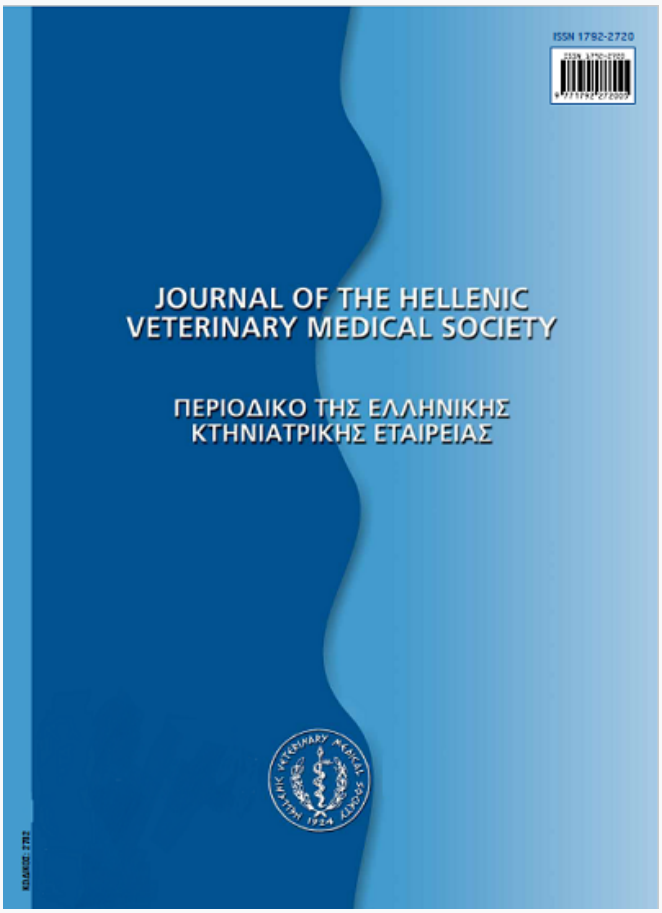

Διερεύνηση συσχέτισης μεταξύ περιβαλλοντικών αλλαγών και κολικού του ίππου

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Research article
Ερευνητικό άρθρο

Correlation between equine colic and weather changes

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Διερεύνηση συσχέτισης μεταξύ περιβαλλοντικών αλλαγών και κολικού του ίππου

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ABSTRACT. The objective of this study is to evaluate the possible correlation between relative humidity/temperature change and equine colic in a specific region of Northern Greece. A study population of 823 adult horses stabled in a 40-km-radius around Thessaloniki, Northern Greece were included in this study; a total of 245 horses, suffering from several types of colic between January 2010 and December 2012 were selected. Metereological data, including temperature (°C) and relative humidity (%) were obtained as 3-hour periodic measurements by the Hellenic National Metereological Service. Statistical analysis was performed using Spearman correlation coefficients in order to assess the relationship between temperature changes, relative humidity changes and equine colic. A positive correlation between temperature change and equine colic was detected during March for the whole 3-year period, while positive correlation was presented during several months of late spring and late fall in specific years. No correlation between changes in relative humidity values and colic was shown. Moreover, a negative correlation between relative humidity and temperature, for temperatures>10°C (rho=-0.568, p<0.01) was found, while, a positive correlation (rho=0.650, p<0.01) between daily temperature

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difference (ΔT) and relative humidity difference was detected. In this study, abrupt temperature change was proven as a significant risk factor in the development of colic during late spring and fall, in Northern Greece, requiring more vigilant horse owners and equine practitioners. These results suggest that in the future it may be possible to modulate management taking into consideration the current weather conditions, in order to prevent colic episodes.

Keywords: horse; colic; weather

ΠΕΡΙΛΗΨΗ. Ο κολικός αποτελεί ένα από τα πιο κοινά προβλήματα του ίππου στην κλινική πράξη και συχνή αιτία θανάτου, εφόσον δεν αντιμετωπιστεί έγκαιρα. Έχουν ενοχοποιηθεί κατά καιρούς διάφοροι παράγοντες που σχετίζονται με την εμφάνισή του όπως η διατροφή, η ηλικία, η κακή κατάσταση των δοντιών, ο ελλιπής αποπαρασιτισμός και οι συνθήκες σταβλισμού. Η μελέτη αυτή περιλαμβάνει 245 περιστατικά κολικών σε ίππους της ευρύτερης περιοχής της Θεσσαλονίκης σε ακτίνα 50 χιλιομέτρων, τα έτη 2010, 2011, 2012. Τα δεδομένα των θερμοκρασιών παραχωρήθηκαν από την Εθνική Μετεωρολογική Υπηρεσία με τη μορφή 3ωρων περιοδικών μετρήσεων και αφορούσαν το σταθμό της Μίκρας-Θεσσαλονίκης. Ακολούθησε στατιστική ανάλυση για να διερευνηθεί η συσχέτιση των μεταβολών θερμοκρασίας και εμφάνισης κολικού κατά την οποία επιλέχθηκε ο συντελεστής συσχέτισης τάξεως Spearman. Με βάση τα διαθέσιμα στοιχεία ανιχνεύθηκε από μέτριας εντάσεως έως ισχυρή θετική, στατιστικά σημαντική συσχέτιση μεταξύ μεταβολών θερμοκρασίας και εμφάνισης κολικού του ίππου για τους μήνες Ιανουάριο, Μάρτιο, Ιούνιο, Οκτώβριο και Νοέμβριο. Με τη μελέτη αυτή αποδεικνύεται ότι οι μεταβολές της θερμοκρασίας αποτελούν σημαντικό προδιαθέτοντα παράγοντα στην εμφάνιση κολικού του ίππου. Ως σύνδρομο πολυπαραγοντικό, περικλείει μεγάλο εύρος δυσκολιών όσον αφορά τον έλεγχο του, ωστόσο, με την εφαρμογή κατάλληλων διαχειριστικών μέτρων και την επαγρύπνηση των ιδιοκτητών, ιδιαίτερα τους συγκεκριμένους μήνες, μπορούν να περιοριστούν τόσο η συχνότητα εμφάνισης όσο και η ένταση των συμπτωμάτων.

Λέξεις ευρετηρίασης: ίππος, κολικός, κλιματολογικές συνθήκες

Abbreviations

ΔT	daily temperature difference
ΔRH	difference between daily maximum and minimum relative humidity values
°C	readings in Celsius

Correlation between equine colic and weather changes

INTRODUCTION

Colic, a broad term used to describe signs that indicate abdominal pain, is one of the most common causes of mortality and morbidity in equine practice (Kaneene et al., 1997;Tinker et al., 1997a). The annual national incidence of colic in a US horse population was estimated to be 4.2 colic events/100 horses per year (Traub-Dargatz et al., 2001). A prospective study (Tinker et al., 1997b) that used 31 horse farms selected randomly from a compiled list of horse farms with greater than 20 horses in USA, reported an overall incidence density rate of 10.6 colic cases/100 horse years, with an incidence density rate of 12.6 colic cases/100 horse years**.** Colic is reported to be the single most common cause of death in some horse populations, representing a mortality rate of 28% (Tinker et al., 1997b). Although the magnitude of the problem is greatly evaluated, relatively little is known about factors that cause it.

Despite the substantial volume of research referring to the multifactorial nature of this syndrome (Reeves, 1997), the exact etiology remains unknown. Many causes of colic are cited but scientific evidence to substantiate these theories is limited. According to literature, a number of factors associated with increased risk of colic have been proposed, including

sex, age, breed, management, increasing exercise, transport, feeding practices and parasite control (Cohen et al., 1996;Cohen et al., 1999; Archer et al.,2006). The association of colic with weather-related factors has been proposed by some authors; however no statistical proof has been reported to substantiate this theory (Cohen, 1997; McCarthy et al., 2001; Gonçalves et al., 2002).

The aim of this study was to evaluate the possible correlation between relative humidity and temperature changes and equine colic in Thessaloniki, Greece over the 3-year period from 2010 through 2012. In this study, an approach has been made to develop the hypothesis that weather change, expressed in a 24-hour basis, may promote equine gastrointestinal disorders.

MATERIALS AND METHODS

Study population and data collection

The study population comprised by 823 horses stabled in premises, covering up an area of 40 km around Thessaloniki. A total of 245 horses were included in this study, suffering from several types of colic between January 2010 and December 2012. More specifically, 13 stallions (5.3%), 132 geldings (53.9%) and 100 mares (40.8%) were examined. The majority of horses were Warmbloods followed by Greek, English Thoroughbreds, Thoroughbred cross, Arabians and Quarter. Their age ranged from 3 to 22 years (median, 13 years). All the horses included in this study were resident on the premises described above, in the same location for the whole 3-year period. Because a specific correlation between equine colic and weather changes was investigated, the project was exclusively based on individual colic cases.

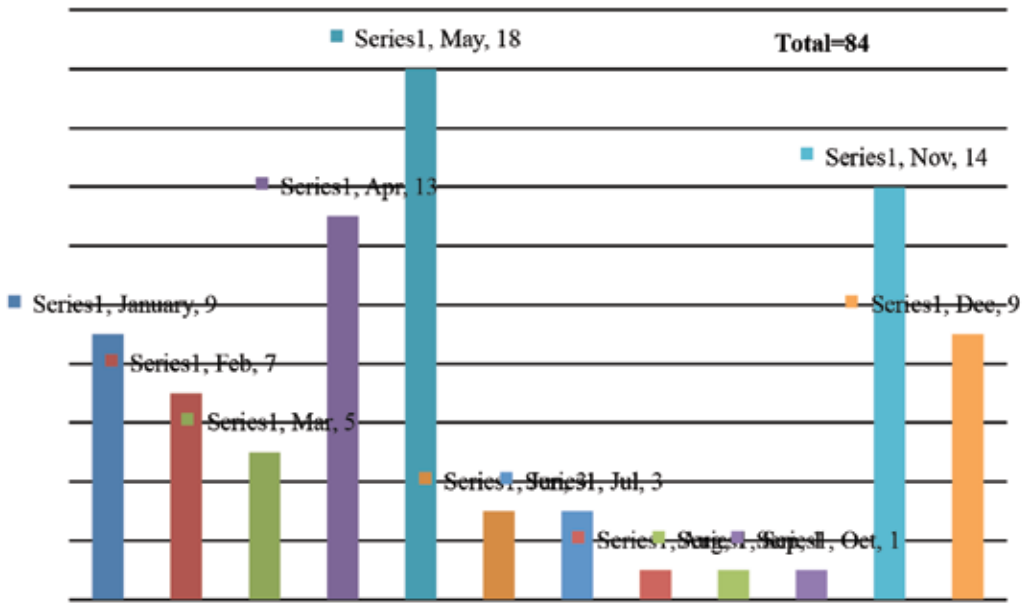
Colic cases that met the inclusion criteria are summarized in the following: enteritis, pelvic flexure impaction, spasmodic colic, cecal/colonic tympany, nephrosplenic entrapment, sand colic, large colon torsion and inconclusive. In the current study, all horses received anti-parasitic paste quarterly and faecal samples were collected regularly to determine the number of eggs/sample.

Metereological Data

Weather data for the 3-year study period, including temperature (°C, readings in Celsius) and relative humidity (%) were obtained as 3-hour periodic measurements by the Hellenic National Metereological Service from the meteorological station of Micra.

Statistical Analysis

Spearman correlation coefficients (Riegelman et al., 1989) were used to assess the relationship between temperature changes, relative humidity changes and equine colic. Pearson's coefficient correlation was used to test the possible correlation between temperature changes and relative humidity changes. For this purpose, the difference between daily maximum and minimum temperature values (ΔT) and the difference between daily maximum and minimum relative humidity values (ΔRH) were calculated. The mean monthly values for temperature and relative humidity



Graph 1. Number of colic cases per month in Year 2010

Table 1. N*=Total number of cases

Diagnosis	N*	P(%)
Enteritis	16	6,5%
Impaction	86	35,1%
Spasmodic colic	107	43,7%
Cecal/colonic tympany	19	7,8%
Nephrosplenic entrapment	2	0,8%
Sand colic	2	0,8%
Large colon torsion	10	4,1%
Inconclusive	3	1,2%

were also determined. For all analyses, a value of $p < 0.05$ was considered significant. All statistical analyses were performed using Statistical Package for the Social Sciences, SPSS Statistics 15.0[a].

RESULTS

The number of colic cases per month for the years 2010, 2011, 2012, as well as the overall number of colic cases in the 3-year period is listed in Graphs **1,2,3,4.** There were an increased number of colic cases during some months of spring and autumn.

For descriptive purposes mean monthly values of temperature were also calculated. A schematic representation of colic episodes in relation to mean monthly value temperatures is shown in **Graph 5.**

Spasmodic colic was the most common case diagnosis, making up 43.67% of the total cases. The second most common type was pelvic flexure impaction, making up 35.10% of colic cases **(Table 1**). Moreover, development of spasmodic colic was also associated to temperature change during the years 2011 ($p<0.006$) and 2012 ($p<0.005$).

The incidence of colic cases in relation to temperature fluctuations are illustrated on **Graphs 6-8.** A narrow 3 or 4 month period, including March, was elected to be presented, during which a strong correlation between temperature change and colic in the 3-year period study was detected.

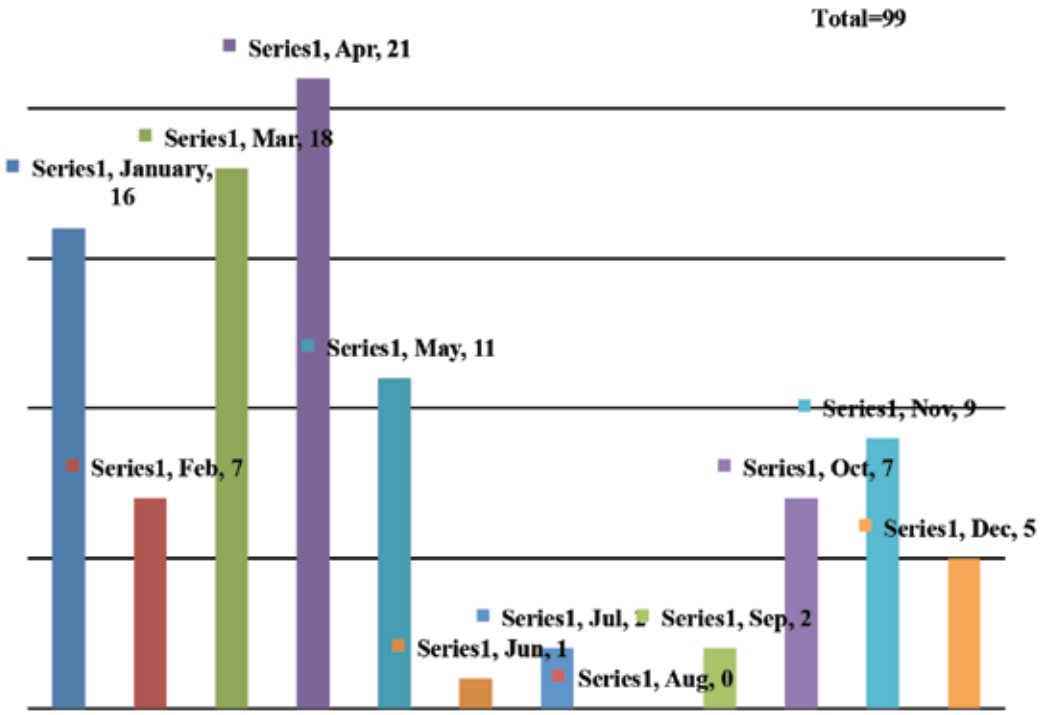
Overall, based on the available data, there seemed to be a positive correlation between temperature change and equine colic. Specifically, a strong positive correlation was found in March for the years 2010 ($rho=0.451$, $p<0.05$) and 2011 ($rho=0.551$, $p<0.01$), while a moderate correlation was shown in March 2012 ($rho=0.383$, $p<0.05$). Furthermore, temperature change was significantly correlated with colic in April ($rho=0.566$, $p< 0.01$), June ($rho=0.387$, $p<0.01$), October ($rho=0.462$, $p<0.01$) and November ($rho=0.499$, $p<0.01$) of the third year. Finally, change in temperature values was moderately correlated with acute abdominal pain in November 2010 ($rho=0.263$, $p<0.05$), November 2011 ($rho=0.296$, $p<0.01$) and December 2011($rho=0.343$). No correlation between changes in relative humidity values and colic was shown.

Over the 3-year period a significant negative correlation between relative humidity and temperature, for temperatures>10°C ($rho=-0.568$, $p<0.01$) was found **(Fig. 1)**. Moreover, there was a strong positive correlation ($rho=0.650$, $p<0.01$) between daily temperature difference (ΔT) and relative humidity difference (ΔRH) (**Fig. 2**). Pearson's coefficient correlation, also used to test the possible correlation between temperature changes and relative humidity changes, revealed a strong positive correlation ($r=0.662$ $p<0.001$).

DISCUSSION

Colic is the most devastating disease in a horse population and one of the most frequent problems encountered by equine practitioners. This study investigated the association between meteorological changes (temperature, relative humidity) and equine colic episodes. Most veterinarians and horse owners tend to relate colic to weather changes; however, some

Graph 2. Number of colic cases per month inYear 2011

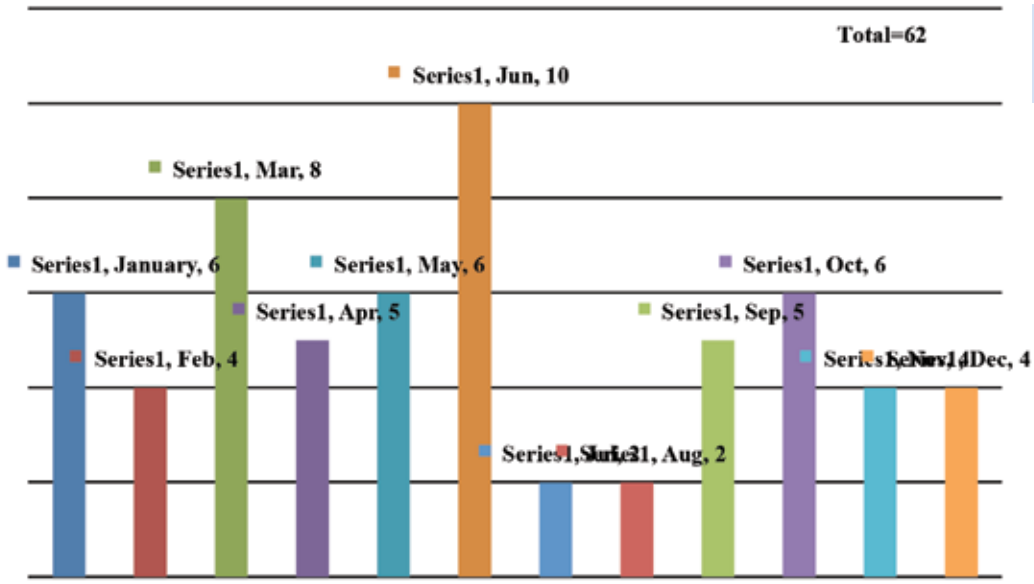


previous studies have been unable to find statistical proof of increased risk (White et al., 2005). A two-year prospective study in UK revealed no significant association between monthly rainfall, temperature and any type of colic (Proudman, 1992). Still, in the same study, an increased incidence of colic during the months of spring and autumn was detected.

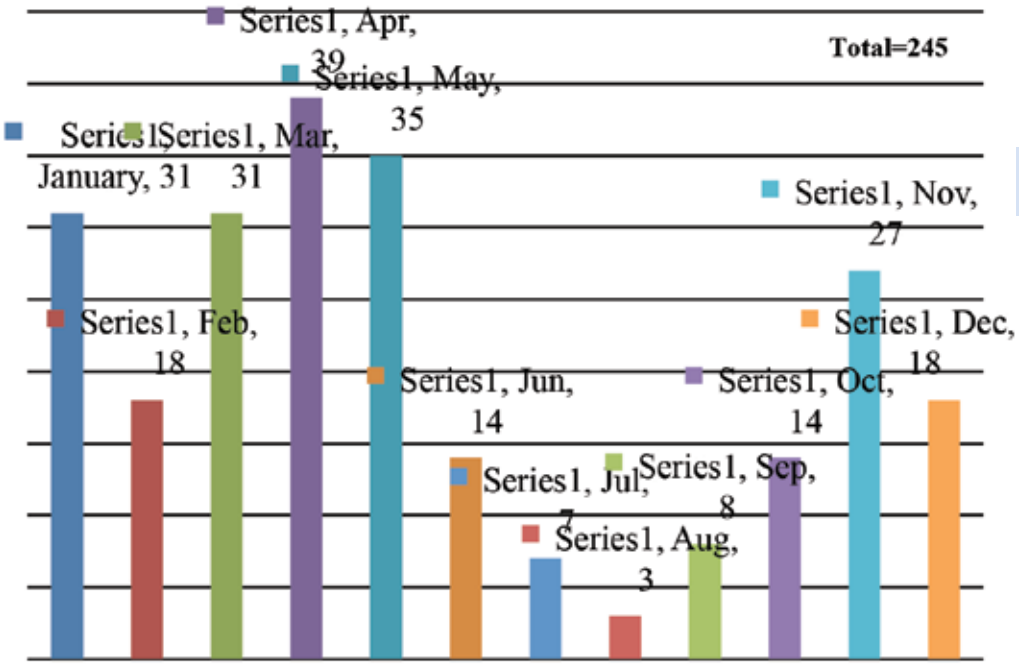
Colic, as a term, comprises a series of conditions recognized to result in abdominal distress. Although details of the intestinal pathophysiology which results in equine colic are not known, common inflammatory responses are evident in all types of colic. It is commonly accepted that exposure to low temperature provokes physiological responses related to the anti-oxidation system, neuroendocrine system and immune system (Onderci et al., 2003;Hekmreich et al., 2005; Hangalapura et al., 2006). A comparative study between healthy horses and horses with colic detected significant association between inflammatory gene expression in leukocytes in the group of sick horses. More specifically, significant differences in expression of some types of interleukin, matrix metalloproteinases and tumor necrosis factor-A genes were found (Lopes et al., 2010). Therefore, in the present study equine colic and its association with weather change, was studied by reference in its entirety.

A seasonal pattern of colic incidence has been supported by a number of reports. A cohort study investigating risk factors for colic in 2060 horses revealed that change in weather during the 3-day period before examination multiplied the risk of colic by 3.2 (Cohen et al., 1999). In a study by Traub-Dargatz et al. (2001), conducted in 1-year period, a higher percentage of colic episodes were reported on spring compared to summer or autumn. In another study Tinker et al. (1997a) reported highest incidence density of colic cases in December, March and August of the study year. This seasonal pattern of colic incidence was also reported in Thoroughbred horses in the British Isles (Hillyer et al., 2001).

In the present study temperature and relative humidity changes in a 24-hour basis were taken as weather parameters possibly associated with colic. Compared to other studies (Tinker et al., 1997a; Tinker et al., 1997b; Cohen et al., 1999), investigating cold weather as direct exposure related to colic, the current study proved an association between temperature changes and incidence of colic, covering a 3-year database of veterinary practitioners including the majority of



Graph 3. Number of colic cases per month in Year 2012



Graph 4. Number of colic cases per month in Year 2012

equine population in the region of Thessaloniki. The current work hopes to augment the existing literature supporting the high incidence of colic during specific months, through a different basis; the daily difference between maximum and minimum temperature (ΔT) values, as well as the daily difference between maximum and minimum relative humidity (ΔRH) values were collected as weather-related factors for possible correlation with development of colic.

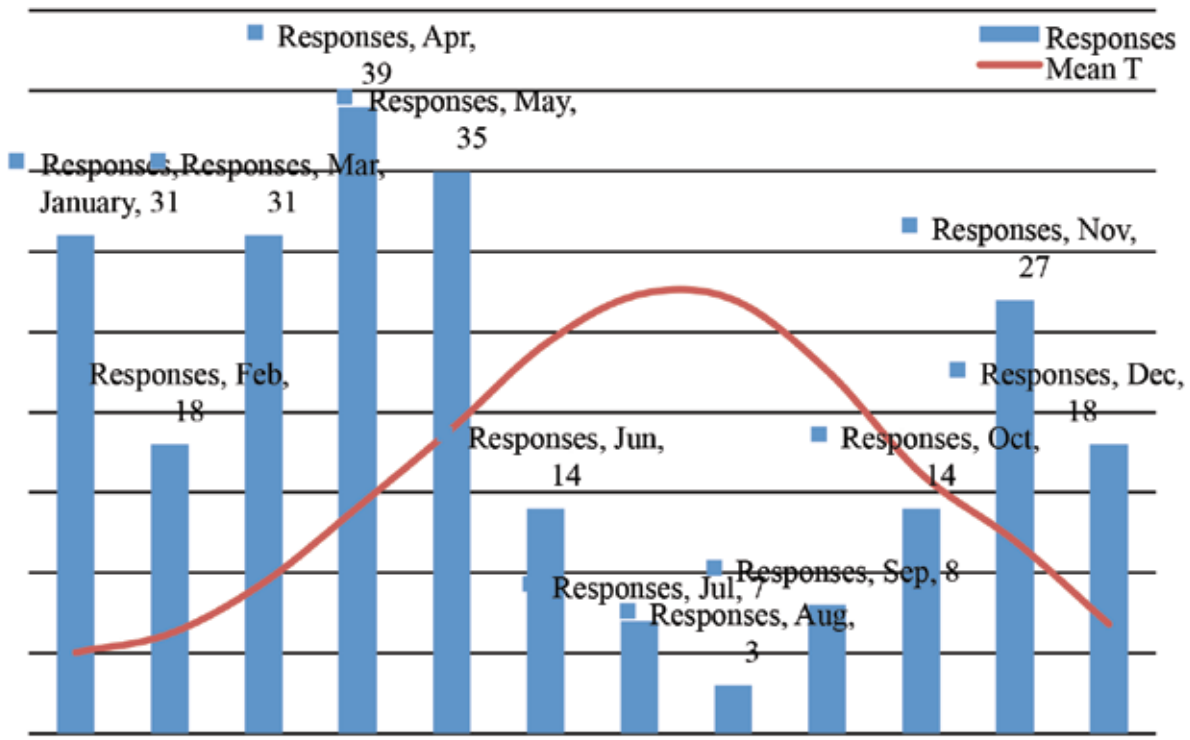
Based on the current results an association between temperature changes and colic has been reported, especially in spring and late autumn, seasons characterized by abrupt and frequent weather fluctuations in Northern Greece. In this study, apart from the fact that a correlation between colic and temperature change was statistically proven, there was also a trend towards a higher incidence of horses with colic in spring. Graphs 6-8 represent colic cases as responses to temperature fluctuations. Hence, a 3-4 month period was chosen, including month of March, during which a strong correlation between temperature change and colic in the

3-year period study was detected. As shown in Graphs 6-8, abrupt temperature change is followed by an increased number of colic incidence a few days later.

There is certain association between weather-related stress and the antioxidant defense system in both human and animal models. It has been indicated that exposure to temperature stress can cause changes in the gastrointestinal micro flora, thus, inducing disturbances in the structure and function of the intestinal tract (Moro et al., 1998;Oliver et al., 2012). Additionally, inflammation and epithelial cell proliferation was reported in the intestine of rats, through a synergistic action of neutrophils, mast cells and nitric oxide (Kaushik et al., 2005). It has also been reported that exposure to low temperature increased change in inducible nitric oxide synthase (iNOS), which was related to the intestinal damage process in broilers (Zhang et al., 2011) and enhanced IL-2 cytokine levels in human models (Janský et al., 1996). Another study investigating the effect of cold stress in mice (4°C/4h daily for 7 days) highlighted the role of macrophages in immunosuppression (Sesti-Costa et al., 2012). Additionally, a recent study revealed that acute and chronic cold stress caused intestinal oxidative stress, through nuclear factors and tumor necrosis factors, associated with breakdown of intestinal homeostasis (Fu et al., 2013). These results expand previous reports referring to the effect of cold stress in glutathione peroxidase metabolism, indicating its possible immune-regulatory impact in visceral organs (Carr et al., 1992;Siems et al., 1994). All these studies, exemplified above, indicate that weather-related stress influenced the function of intestinal tract of human and animal models.

Based on the results of this report, development of colic is positively correlated with temperature change. As far as humidity is concerned, no correlation between changes in relative humidity and equine colic was detected. The strong negative correlation between daily temperature (T) and relative humidity (RH), for temperatures for temperatures>10°C, calculated for descriptive purposes, can further support that fact. Although relative humidity is considered to have an important impact in immune barrier (Elias, 2007) public health issues, facilitating disease transmission (Lowen et al., 2007), there is no reported evidence to support its possible role as a single factor in the development of colic in human or animals (Al-Hadramy, 1997;Dennler et al., 2005).The failure to demonstrate the possi-

Graph 5. Number of colic cases per month (Responses) in correspondence to mean monthly temperature (Mean T)



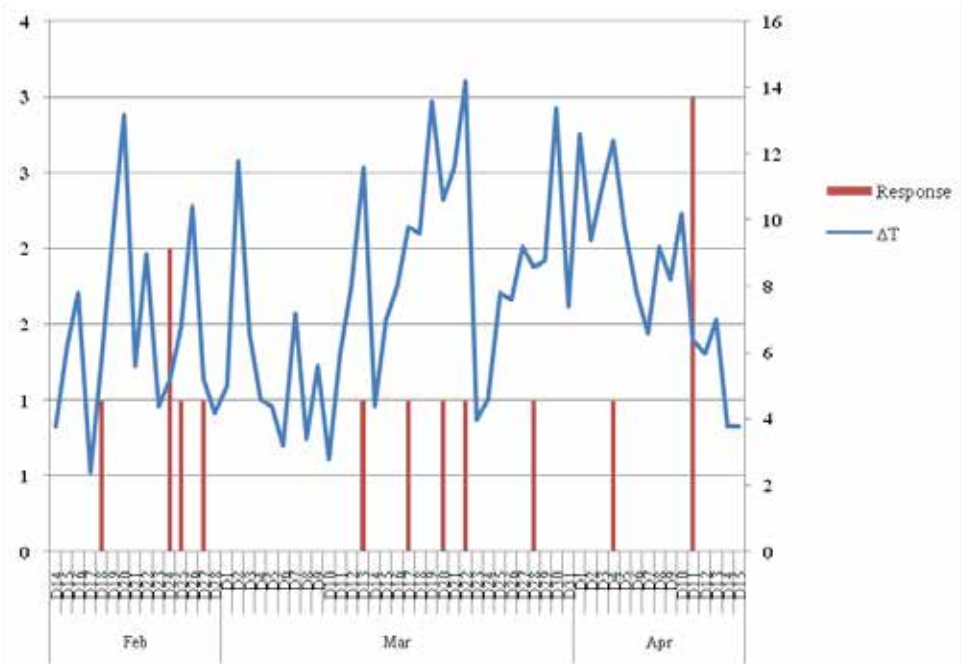
ble correlation between relative humidity and biological responses referred to other species is also reported (Al-Hadramy et al., 1997;Dennler et al., 2005) intensifying the need for an alternative approach. Taking into consideration the close relationship between relative humidity and temperature, also underlined in this study, other reports investigated these two climatic variables, combined as input, examining heat stress in Mediterranean dairy sheep (Finocchiaro et al., 2005).

In this report, two closely related climatic variables, relative humidity and temperature, and their possible impact on equine colic, were investigated. A high incidence of colic episodes was detected, especially during the months of spring and autumn. According to previous studies, various meteorological factors have been suspected to contribute to several clinical manifestations in human and animal models. Association between weather and pain among individuals with osteoarthritis (Wolder et al., 2003) and rheumatoid arthritis (Strusberg et al., 2002) has been evaluated. Moreover, a correlation has been detected between changes in barometric pressure and the onset of labor (King et al., 1997) and sudden infant death syndrome (Cambell et al., 2001). A retrospective study conducted in military working dogs in Texas revealed that an increased risk of gastric dilatation-volvulus was associated with the occurrence of abrupt hourly drops in temperature and of higher minimum barometric pressure in that day and the day before the occurrence (Moore et al., 2008). Experimental animal behavioral studies carried out in male rats demonstrated a consistent association between changes in weather related factors and pain intensity (Sato, 2003).

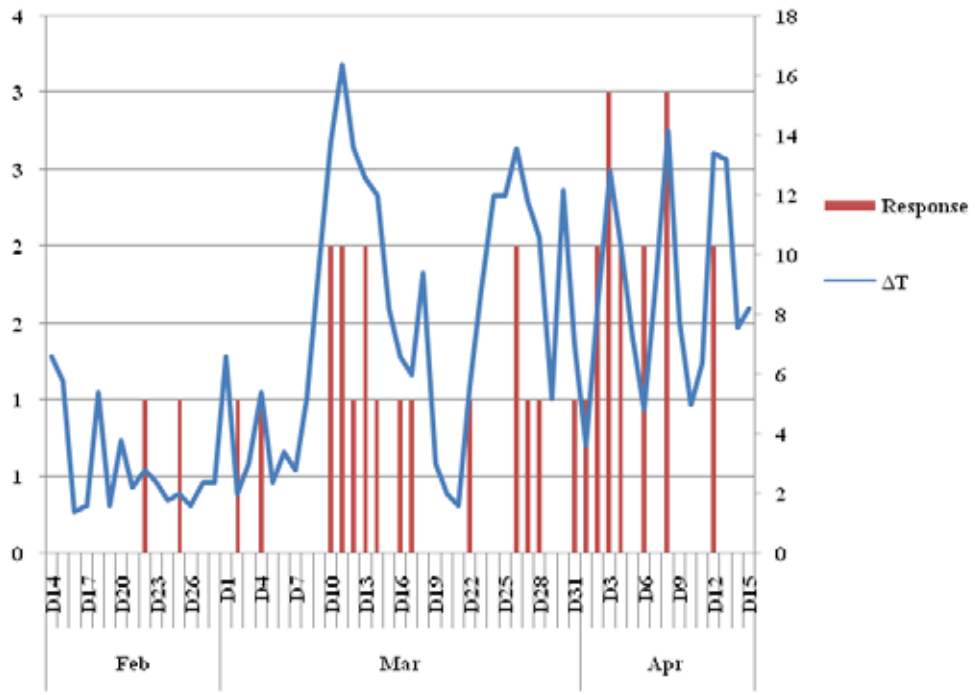
It is important to bear in mind, however, the multifactorial nature of this syndrome. While colic is considered to affect horses of any breed, several studies suggest an increased incidence of disease in certain breeds, such as Thoroughbred horses (Traub-Dargatz et al., 1999) and Arabians (Cohen et al., 1996). Nevertheless, marked attention should be paid to the similarity of the sample to population, as some breeds might be overrepresented. Young horses are more prone to ileocecal intussuseptions, while middle-aged horses are at higher risk than older horses (Proudman, 1992). Among the aforementioned intrinsic factors, gender is considered to be included for conditions such as inguinal hernia in stallions and peripartum colic in mares.

Specific types of colic are presented with higher incidence in some geographic regions; enteroliths are

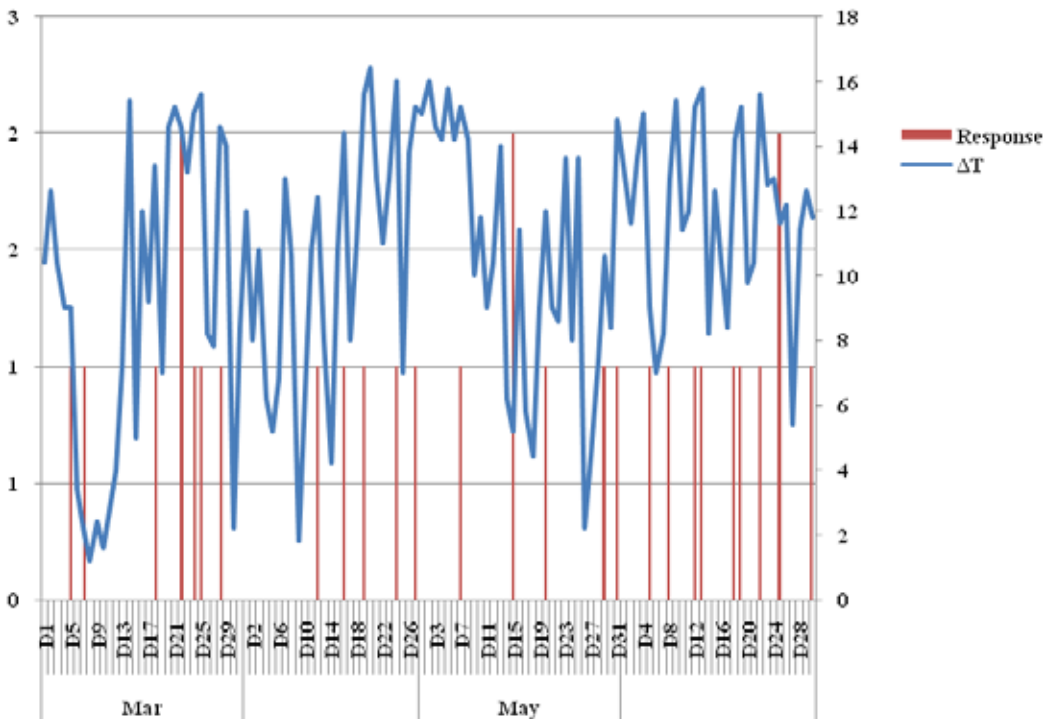
Graph 6. Year 2010: Colic cases- Responses to temperature fluctuations. ΔT is the difference between daily maximum and minimum temperature values



Graph 7. Year 2011: Colic cases- Responses to temperature fluctuations. ΔT is the difference between daily maximum and minimum temperature values



Graph 8. Year 2012: Colic cases- Responses to temperature fluctuations. ΔT is the difference between daily maximum and minimum temperature values



more frequently observed in horses in California, the Midwest, and Florida (White, 1990), grass sickness is diagnosed in Europe (McCarthy et al., 2001;Protopappas et al., 2012), while sand colic impactions are reported in horses that graze on sandy soils or are forced to eat off ground. Furthermore, dietary management consisting large amount of grain (White, 2006) and transport are thought to be associated with increased risk of colic (Hillyer et al., 2002). It has been proposed that cold weather was linked to increased incidence of impaction colic, possibly because of decreased water intake, although when examined as a direct exposure factor in a Virginia-Maryland study, weather did not appear a correlation (Tinker et al., 1997a).

Spasmodic colic was the most commonly reported type of colic in this study, supporting previous reports of Foreman and White (1986). It is worth mentioning, though, that development of spasmodic colic was also statistically associated to temperature change during the last two years of survey, extrapolating other reports that investigated risk factors for this specific type of colic (Proudman et al., 1998). Bearing in mind that horses in this study were parasite - free, it can be postulated that stress, weather related or other, was the main cause of this type of colic.

Although this study has statistically proven a correlation between equine colic and weather change, it comes with certain limitations. In the current study, two variables, temperature and relative humidity change were chosen as weather-related factors possibly associated with equine colic in a specific regional area of Northern Greece; a seasonal incidence was detected while abrupt change in temperature values has proved to be a significant risk factor. Despite the lack of a multivariate analysis, the sizeable equine population (823 horses) provided reliable results regarding the association between meteorological changes and colic in a specific geographic location in Greece.

CONCLUSIONS

Along with the aforementioned colic-related factors, the results of this study may be counted in so as to promote adequate preventative methods and more vigilant horse owners, especially when abrupt temperature changes are expected. Understanding the incidence, as well as the economic role of colic, these data suggest that in the future it may be possible to modulate management factors and monitoring, depending on the predictable weather conditions in order to avoid, as much as possible, the occurrence of colic. Horse owners should be made aware of the significance of weather change as a considerable risk factor, and therefore, should be advised of measures that may be implemented. Further research may be required to pathophysiologically define the role of temperature changes as causing factor of equine colic.

Source of funding

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Conflict of interest

The authors of this paper certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethical Considerations

On behalf of all authors is certified that legal and ethical requirements have been met with regards to the humane treatment of animals described in the study.

Footnotes

a. SPSS Inc. Released 2006. SPSS for Windows, Version 15.0 Chicago, SPSS Inc

Figure 1. Graph showing correlation between relative humidity (RH) and temperature (T) for the 3-year period. The red best fitted line was plotted by means of the Loess smoothing method. (Jacoby, 2000)

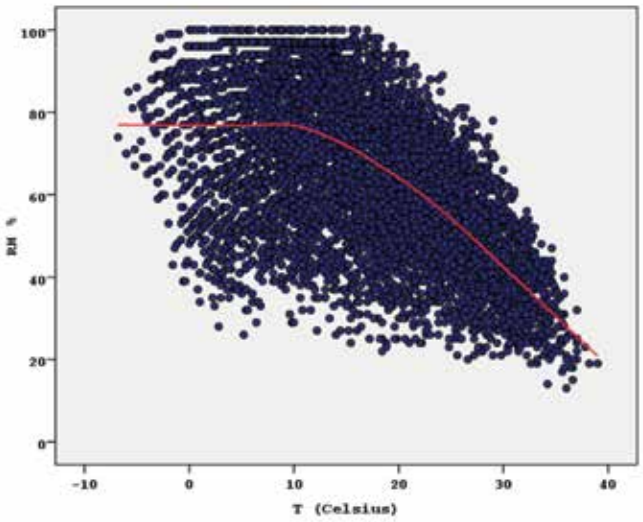
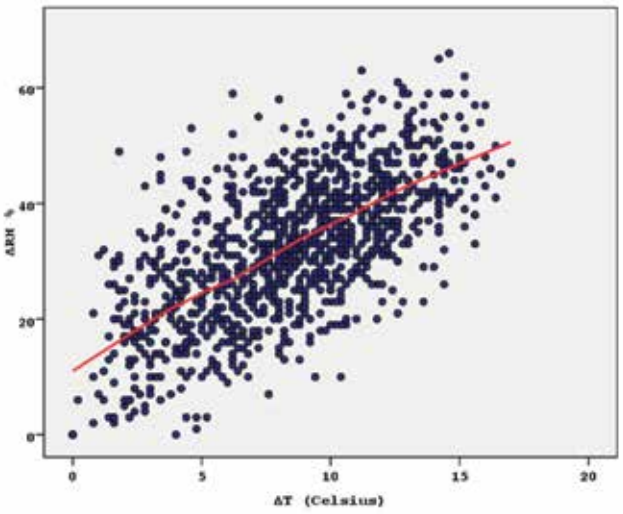


Figure 2. Graph showing correlation between daily relative humidity difference (ΔRH) and temperature difference (ΔT) for the 3-year period



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