ความชุก การรับรู้ และปัจจัยที่มีผลต่อภาวะอ้วนของสุนัขในประเทศไทย

นางสาววรางคณา เถาธรรมพิทักษ์

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Prevalence, perception and risk factors of canine obesity in Thailand

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วรางคณา เถาธรรมพิทักษ์ : ความชุก การรับรู้ และปัจจัยที่มีผลต่อภาวะอ้วนของสุนัขในประเทศไทย (Prevalence, perception and risk factors of canine obesity in Thailand) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. อัจฉรา ธวัชสิน, 71 หน้า.

สัดส่วนของสุนัขอ้วนเพิ่มขึ้นทั่วโลก และเป็นเรื่องที่ถูกให้ความสนใจมากขึ้น เนื่องจากมีผลลดคุณภาพชีวิตของสุนัขและทำให้อายุขัยของสุนัขสั้นลง วัตถุประสงค์ของการศึกษานี้เพื่อหาความชุกของสุนัขอ้วนและปัจจัยเสี่ยงที่เกี่ยวข้องกับภาวะอ้วนของสุนัขในประเทศไทย หาความเข้าใจผิดของเจ้าของต่อรูปร่างของสุนัขและหาความสัมพันธ์ระหว่างภาวะอ้วนของสุนัขและค่าทางชีวเคมี ทำการศึกษาแบบ cross-sectional study โดยศึกษาในสุนัขที่มีอายุมากกว่า 1 ปี ไม่จำกัดเพศ สายพันธุ์และปัญหาสุขภาพจาก 6 ภาคของประเทศไทย (n=2,401) จากผลการศึกษาพบว่าความชุกของสุนัขอ้วนเท่ากับ 42.94% จากการวิเคราะห์แบบหลายตัวแปร พบว่าปัจจัยเสี่ยงที่จะทำให้สุนัขอ้วน คือ อายุ 3-8 ปี (OR=1.98) ทำหมัน (OR=1.63) ได้รับขนมสุนัขทุกวัน (OR=1.47) และมีสุนัขในบ้านเดียวกันมีภาวะอ้วน (OR=2.37) การศึกษาเปรียบเทียบผลการประเมินรูปร่างของสุนัขโดยเจ้าของและสัตวแพทย์ ผลการศึกษาพบว่าผลการประเมินมีความไม่สอดคล้องกัน ($p<0.0001$) โดยมีเจ้าของ 18.5% ที่ประเมินรูปร่างของสุนัขตัวเองต่ำกว่าความเป็นจริง ปัจจัยเสี่ยงที่ทำให้เจ้าของประเมินรูปร่างสุนัขต่ำกว่าความเป็นจริง คือ อายุมากกว่า 8 ปี (OR=1.90) และทำหมัน (OR=1.26) ทำการเจาะเลือดสุนัขเพื่อนำไปตรวจค่าทางโลหิตวิทยาและค่าทางชีวเคมีในสุนัข 2 กลุ่ม คือ สุนัขที่สุขภาพดีและไม่อ้วน (n=50) และอ้วน (n=50) ผลการศึกษาพบว่าระดับของ total cholesterol และ triglyceride ในสุนัขอ้วนสูงกว่าสุนัขที่ไม่อ้วน ($p<0.05$)

โดยสรุปคือการศึกษานี้เป็นการศึกษาเรื่องความชุกของสุนัขอ้วนเป็นครั้งแรกในประเทศไทย โดยมีความชุกของสุนัขอ้วนสูงถึง 42.94% นอกจากนี้เจ้าของสุนัขยังประเมินรูปร่างของสุนัขผิดไป ทำให้ไม่ได้ใส่ใจและเป็นอุปสรรคในการควบคุมน้ำหนักของสุนัข ค่าทางชีวเคมีอาจสามารถใช้ในการตรวจวินิจฉัยเพื่อให้เจ้าของตระหนักถึงภาวะนี้เพิ่มขึ้น ภาวะอ้วนเป็นส่วนหนึ่งที่ควรจะถูกคำนึงถึงเมื่อทำการตรวจสุขภาพทั่วไปของสุนัขและการให้ความรู้กับเจ้าของสุนัขมีความจำเป็นอย่างยิ่งเพื่อทำให้การควบคุมน้ำหนักสุนัขประสบผลสำเร็จ

ภาควิชา อายุรศาสตร์ ลายมือชื่อนิสิต ....

สาขาวิชา อายุรศาสตร์สัตวแพทย์ ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

ปีการศึกษา 2559

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VARANGKANA THAOTUMPITAK: Prevalence, perception and risk factors of canine obesity in Thailand. ADVISOR: ASSOC. PROF. ACHARA TAWATSIN, B.Sc., M.Sc., 71 pp.

The proportion of obese dogs is increasing worldwide. It has become a topic of interest as it can impair quality of dog's life and reduce longevity. The objectives of this study were to determine prevalence and risk factors of canine obesity in Thailand, misperception of owner on body shape of dogs and relationship between canine obesity and laboratory parameters. A cross-sectional study was performed with dogs aged over 1 year regardless of breed, sex and health status from 6 regions of Thailand (n=2,401). Results showed that prevalence of canine obesity was 42.94%. Risk factors by multivariable analyses were age 3-8 years old (OR=1.98), neutering (OR=1.63), snacking once daily (OR=1.47), and having obese dogs in the same household (OR=2.37). A comparison of body shape evaluation by owners and veterinarian showed discrepancy of these two assessments ($p<0.0001$) with 18.5% of dog owners underestimated their dogs' body shape. Risk factors of underestimation were age >8 years old (OR= 1.90) and neutering (OR= 1.26). Blood collection was done for hematology and blood chemistry profile evaluation in two groups of dogs; clinically healthy non-obese dogs (n=50) and obese dogs (n=50). Total cholesterol and triglyceride were higher in obese dogs compared with non-obese dogs ($p<0.05$).

In conclusion, this is the first report about prevalence of canine obesity in Thailand. The high prevalence of obesity was found in this study (42.94%). In addition, misperception of owner on evaluation of body conformation may lead to lack of concern and being an obstacle for weight control regimen. Some laboratory parameters may be used as a diagnostic tool to promote awareness of the owners. Canine obesity should be considered as a part of basic health program and client education is needed in order to have successful control of canine obesity.

Department:	Veterinary Medicine	Student's Signature	....
Field of Study:	Veterinary Medicine	Advisor's Signature	....
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LIST OF ABBREVIATION

AKC	American Kennel Club
ALP	Alkaline phosphatase
ALT	Alanine transaminase
AST	Aspartate transaminase
AUC	Area under the curve
BC	Body conformation
BCS	Body condition score
BIA	Bioelectrical impedance analysis
BMI	Body mass index
BW	Body weight
°C	Celsius
CI	Confidence interval
DEXA	Dual energy x-ray absorptiometry
dL	Deciliter
EDTA	Ethylenediaminutesetetraacetic acid
Exp (β)	Exponential of regression coefficient
FCI	Federation Cynologique International for dogs worldwide
FFM	Fat free mass
G	Gram
HRQL	Health Related Quality of Life
IGF-1	Insulin-like growth factor
Kg	Kilogram
L	Liter
m	meter
MFBIA	Multi-frequency bioelectrical impedance analysis
mg	milligram
N	number of dogs
OR	Odds ratio

OSA	Osteosarcoma
RCF	Relative centrifugal force
REE	Resting energy expenditure
Ref	Reference
S.D.	Standard deviation
S.E.	Standard error
T_3	Triiodothyronine
T_4	Thyroxine
Total T_4	Total thyroxine
TRH	Thyrotropin-releasing hormone
TSH	Thyroid-stimulating hormone
U	Unit
WIWDR	waist-to-ilium wing distance ratio
WTLR	waist-to-truncal length ratio
β	Regression coefficient
μg	microgram

Chapter I

Introduction

Importance and Rationale

Obesity is a common nutritional problem in which excess body fat leading to harmful effects on health. This condition has been of highly concern for human health in the past decade. As for small animal practice, it has also been growing interest in dogs and cats. Obesity in dogs has been shown to be related to several factors involving either dogs or pet owners. Several reports showed that owners' lifestyle and feeding behavior play an important role in their pet condition. Additionally, the misperception and reluctance of owners towards dog obesity is a major obstacle for treating dogs in weight loss program. Generally, the prevalence of obesity in dogs ranges between 34.1-53.9% (Lund et al., 2006; Courcier et al., 2010). Reportedly, obesity can lead to a various health problems such as osteoarthritis, expiratory dysfunction, musculoskeletal disorders, cardiovascular disorders, glucose intolerance, diabetes mellitus, impaired fertility and mammary cancer (Impellizeri et al., 2000; Bach et al., 2007; Thengchaisri et al., 2014). Additionally, reduction in lifespan of obese dogs has also been reported (Kealy et al., 2002).

There have been attempts to set a precise measurement of canine obesity. In clinical practice, standard protocols of body condition score 5 point-scale and 9 point-scale were created and accepted worldwide (Laflamme, 1997). However, these protocols are subjective estimation with individual variation. Furthermore, a previous published study suggested misclassification of body condition score by owner assessment (Eastland-Jones et al., 2014). In human, body mass index (BMI) is generally applied to assess and to monitor obese condition. This method has low variation and does not depend on age, sex and race. In contrast, dogs have a variety of breeds, therefore, resulting in a difference of BMI standard range, when using the height defined as the length of whole body as in human. Later, modified body mass index was generated by using the height at shoulder point or truncal length instead of height of dogs (Thengchaisri et al., 2014; Ajadi et al., 2016). In addition, other morphometric methods (i.e. waist-to-hock-to-stifle distance ratio, waist-to- ilium wing distance ratio and waist-to-truncal length ratio were established, but they were restricted to figure out the association with specific heart disease (Thengchaisri et al., 2014). Lately, plasma lipids (cholesterol and triglyceride) and plasma lipoprotein classes of cholesterol or triglyceride were suggested as potential indicators for obese dogs, even though these parameters were influenced by age, gender, breed, neuter status and fasting time before blood tests (Peña et al., 2008; Mori et al., 2011; Usui et al., 2015). So far, there has been no report indicating these parameters as a good index for accurate diagnosis.

Recently, a new study showed the increasing trend of body mass index in Thai adults during 1991-2009 (Aekplakorn et al., 2014). According to previous studies, there was a relationship between owners' and pets' body condition (Heuberger and Wakshlag, 2011). However, there have been no reports of this relative aspect of dogs in Thailand. This study aimed to prove the existence of canine obesity in Thailand and to investigate the important risk factors related with canine obesity in Thailand. Reducing or avoiding these risk factors could be used as a part of monitoring or prevention of obesity in dogs.

Objectives of Study

1. To investigate the existence, prevalence, perception and risk factors of canine obesity in Thailand
2. To determine the relationship between canine obesity and laboratory parameters

Hypothesis

1. The prevalence of canine obesity in Thailand is lesser than or equal to 44.4%
2. There is a misperception between owner and veterinarian assessment
3. Age, breed, gender, neuter status, food type, frequency of feeding, feeding snack or treat, living style, concurrent diseases and body mass index of owner are important risk factors of canine obesity
4. There is a relationship between ALT, ALP, cholesterol, triglyceride, total protein, albumin and total T_4 with the obese condition of dogs in Thailand

Keywords (Thai): สุนัข, ภาวะอ้วน, ความชุก, ปัจจัยเสี่ยง

Keywords (English): dog, obesity, prevalence, risk factor

Advantages of Study

This study will provide the database of prevalence and risk factors of obesity in dogs in Thailand leading to awareness of pet owners regarding obesity. Control of risk factors may lower the incidence of obesity in dogs and should be recommended for individual weight loss program.

Chapter II
Literature review

Etiology and pathophysiology of obesity

Obesity in dogs is generally considered as a consequence of excessive energy uptake and inadequate energy expenditure. Various mechanisms controls energy uptake and energy expenditure regard to neuro-endocrine system and cognitive function to determine amount of food intake (Backus and Wara, 2016). Previous study mentioned that appearance, odor and taste as well as experience are the first key features to initiate food intake (Backus and Wara, 2016). Later, activation of chemoreceptors in proximal gastrointerstinal tract creates satiation signals that effect meal size and duration of ingestion. Various hormones (especially insulin) are secreted and play important role to promote nutrients absorption from digested food into the cells. In late ingestive phase, meal termination is generated by glucose combined with early satiation signal.

There is a marked variation in energy expenditure of dogs depending on age, breed, health status, environment temperature and physical activities. In small animal practice, resting energy expenditure (REE) can be calculated using formula as shown below.

Resting energy expenditure = $70\times$ kg $BW^{0.75}$; for dogs with any weight

Resting energy expenditure = $70 + 30 \times$ kg BW; for 2 kg$\leq$ dogs $\leq$ 25 kg

Initially, body weight (BW) can use current body weight for the formula but ideal body weight is recommended and more preferable (Hill, 2006). Any causes that affect energy intake and energy expenditure can result in obesity.

Canine obesity

Obesity in dogs is defined as an excess of body weight of 15% or more compared with ideal body weight (Laflamme and Kuhlman, 1995). Survey studies have been conducted in different geographic areas. The prevalence of obesity from these studies ranged from 25.2-59.3% (Table 1). However, there have been no previous report on canine obesity in Thailand and Southeast Asia.

Table 1 Previous surveys about the prevalence of canine obesity

Location (year of study)	N	Prevalence (%)			Reference
		Overweight	Obese	Total	
Australia (2000)	2,661	33.5	7.6	41.1	McGreevy et al., 2005
Franch (2003)	616	33.8	5.0	38.8	Colliard et al., 2006
US (1995)	21,754	29.0	5.1	34.1	Lund et al., 2006
US (1999-2004)	14,670	14.8	21.6	36.4	Weeth et al., 2007
UK (2007)	696	38.9	20.4	59.3	Courcier et al., 2010
China (2008-2011)	2,391	44.4		44.4	Mao et al., 2013
Japan (2006-2013)	9,120	39.8	15.1	54.9	Usui et al., 2016

Impact of obesity in dogs

Currently, awareness about this problem is increasing worldwide because it has been proved to potentially exaggerate many serious clinical comorbidities. Moreover, it has become more prevalent in dogs in the last decade (Mao et al., 2013; Usui et al., 2016). This condition can cause negative effects on multiple organs systems, such as, osteoarthritis, expiratory dysfunction, musculoskeletal disorders, cardiovascular disorders, glucose intolerance, diabetes mellitus, impaired fertility and mammary cancer (Impellizeri et al., 2000; Bach et al., 2007; Thengchaisri et al., 2014). Recently, a study showed the positive relationship between obese dogs and asymptomatic urinary tract infections (Wynn et al., 2016). This condition may prone the dogs to ascending infection and calculi. Additionally, the life span of obese dogs is often reduced (Kealy et al., 2002).

Presently, a proportion of old dogs is increasing according to longer life span of the dogs. With longer life span, diseases related to aged condition can also increase in geriatric dogs. Tumor is one of the highly concerned diseases in small animal practice because it is always uncured with high rate of recurrence. Preliminary experiment in *S. typhimurium* strain TA98 and TA100 with Thai local brand dry dog food presented potential of mutagenesis (Khuntamoon et al., 2016). Although, the association of the obesity and tumorigenesis was not clearly demonstrated (Weeth et al., 2007). There are various types of cancer and individual cancer characteristics. Interestingly, there is an association between obesity and certain types of tumors. For example, mammary gland tumor and mast cell tumor are related to canine obesity (Weeth et al., 2007) while there is no association of obesity in dogs with lymphoma and osteosarcoma (OSA) (Romano et al., 2016).

Obesity can affect dog's health and quality of life. A study about Health Related Quality of Life (HRQL) using a validated online questionnaire assessed by dog owners and automatically reported the final scores of each dog (Yam et al., 2016). This study showed that the overweight/obese dogs significantly decreased score of 2 domains of HRQL-energetic/enthusiastic and active/comfortable as compared with non-obese dogs. This can conclude that overweight/obese dogs are more likely to reduce the capacity of mechanical movement and may increase the pain score from excess body weight. Additionally, a study showed that successful weight reduction of obese dog can increase HQRL (Yam et al., 2016) and decrease pain scores (German et al., 2012).

Risk factors related with canine obesity

The causes of obesity include both owner and dog factors. The following factors were reported in studies related with canine obesity.

Age

Most of the published studies showed that old aged dogs are risk for obesity (Colliard et al., 2006; Mao et al., 2013). Although, some studies showed that middle-aged dogs are at the highest risk for being obese (McGreevy et al., 2005; Courcier et al., 2010). Weight control program of young to middle-aged dogs is recommended (Lund et al., 2006).

Gender

There have been several reports showed higher prevalence of obesity in female than male dogs (McGreevy et al., 2005; Colliard et al., 2006; Mao et al., 2013; Usui et al., 2016). In human, similar results were found in which women are at higher risk of obesity because they eat more fat and inadequate essential nutrients intake (Ledikwe et al., 2003). However, this association in dogs is still inconclusive.

Neuter status

Castrated male dogs and spayed female dogs being risk for obesity have been reported in previous studies (Robertson, 2003; McGreevy et al., 2005; Colliard et al., 2006; Lund et al., 2006; Mao et al., 2013; Usui et al., 2016) and intact dogs are low risk for obesity. This is believed to be related to hormonal changes, especially estrogen and androgen (Zoran, 2010). Furthermore, neutered dogs were likely to be inactive (Laflamme, 2012) leading to low energy expenditure (Jeusette et al., 2006) and contributing to obesity.

Breed

Dogs have a variety of breeds and sizes. A study proposed that there was difference of level of energy expenditure in regards of breeds (Usui et al., 2016). Some certain breeds, i.e. Beagle, Shetland Sheepdogs, Cocker Spaniel, Labrador Retriever, Golden Retriever, Rottweiler, Dalmatian, Dachshund and Australian working dogs, were reported that they tended to be obese easily (McGreevy et al., 2005; Colliard et al., 2006; Lund et al., 2006). Additionally, crossbred dog and medium size dogs were also associated with high probability of obesity (Mao et al., 2013; Usui et al., 2016). Further studies are needed to find out factors related with this dissimilarity.

Food

Food types have a great impact on obese condition in dogs. Interestingly, non-commercial food, home-prepared or table scraps, were the most popular choices of dog food worldwide, including in the US (Heuberger and Wakshlag, 2011) and China (Mao et al., 2013). So, it is hard to estimate the dogs' caloric intake to meet nutritional requirement as a result of energy imbalance and excessive body weight. A similar findings, semi-moist food, homemade food, table scraps, home-prepared and non-commercial food made dogs risk for obesity, have been reported (Colliard et al., 2006; Lund et al., 2006; Mao et al., 2013). Additionally, a study was noted that food factors related with dog obesity are complex (White et al., 2016). A study about favors of owners to select dog food was investigated in respect of obese and non-obese dogs. It showed that owners with obese dogs highly concerned to select dog foods with low price and special offers of commercial food and less of concern in quality of ingredients and nutritional composition compared with owners with non-obese dogs (Suarez et al., 2012). This is related to previous survey that owners with low income are at more risk for having obese dogs (Courcier et al., 2010).

Frequency of feeding

Finding of association between obese condition and frequency of feeding in dogs were controversy. Some studies presented that dogs fed once daily are at risk for obesity (Robertson, 2003; Courcier et al., 2010), while a report found that dogs ate frequently are more prone to obesity (Mao et al., 2013). This association in dogs was not clear.

Feeding snacks and treats

Snacks and treats are of more concern than food by some dog owners. They still plays important role in human-pet bond. Many owners feed their dogs with treats at least once daily, although they had low income (Sapowicz et al., 2016). There was the discrepancy of responses related with feeding snacks and treats. In general, owners define anything apart from routine meal as a snack. Even though, the dogs are not fed with meal properly, owners still feed their dogs with snack on daily basis (White et al., 2016). The study in Australia showed that feeding with snacks in dogs is associated with an increased risk of obesity (Robertson, 2003).

Living style

Physical exercise is related with energy expenditure and reduction in risk of canine obesity. Dogs kept in door or living in restricted area were reported to be risk for obesity (Colliard et al., 2006; Mao et al., 2013). Although, one report in Australia declared that dogs in rural area are at high risk for obesity because dogs can access food sources easily and unlimited (McGreevy et al., 2005).

Concurrent diseases

Previous study reported that canine obesity is associated with many serious diseases, such as, hyperadrenocorticism, hypothyroidism, rower urinary tract disease, ruptured cruciate ligament, neoplasm, diabetes mellitus and pancreatitis (Lund et al., 2006). However, the pathogenesis is still unclear. There has been no previous report about having multi-diseases and obese condition in dogs.

Measurement of obesity

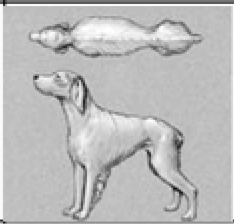
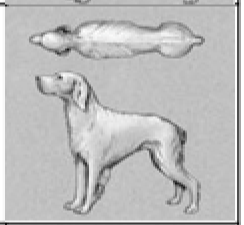
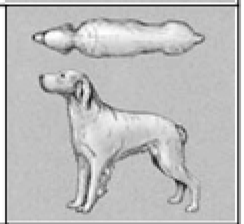
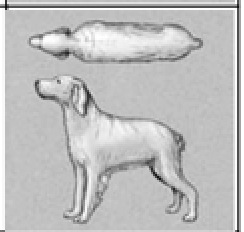
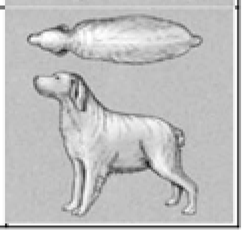
Evaluation of canine obesity and monitoring body condition of dogs can be accomplished in many ways. In experiments, the gold standard method is the dual energy x-ray absorptiometry (DEXA). This method uses two low energy x-ray beams that are attenuated by bone and soft tissue to produce a radiographic image, in which, is analyzed to obtain the exact body fat composition (Laflamme, 1997). However, dogs must be anaesthetized and the whole body calculating program is used. This method is suitable for dogs weighing over 10 kilograms. Therefore, this method is difficult to perform in a routine practice since it sophisticated technology and facilities are required. Alternative non-invasive methods, such as, Bioelectrical Impedance Analysis (BIA), which measures the resistance to an electrical signal sent through the water that is found in muscle and fat (Kyle et al., 2004). This related with fat free mass in dogs' body. Multi-frequency Bioelectrical Impedance Analysis (MFBIA) was recently developed to measure Fat Free Mass (FFM) accurately when compared with the DEXA as reference (Rae et al., 2016). Body Mass Index (BMI), a comparison ratio between body weight and height at shoulder multiplied with the distance between the occipit and base of tail, can give similar body composition results to DEXA results (Jeusette et al., 2010). However, these methods are time consuming and cannot easily be used to evaluate a large number of dog samples.

In general practice, body condition score is the most frequently used method with using visual inspection and palpation to assess the dog body fat. However, it was subjective measure and not reliable because it depends on skill and experience of veterinarian. There are scales of 5, 7, and 9 (Laflamme, 1997; Courcier et al., 2010).). The 5-scale BCS is the most common and widely accepted in general practice (McGreevy et al., 2005; Lund et al., 2006; German et al., 2009). The explanation of each score is shown in Table 2. However, some publication still demonstrated that using validated chart of BCS cannot improve owner assessment accurately, the owners still underestimated their dog body shape (Eastland-Jones et al., 2014). Recently, a report demonstrated that morphometric methods, for example, Waist-to-Ilium Wing Distance Ratio (WIWDR) and Waist-to-Truncal Length Ratio (WTLR) are useful to find out this condition in dogs as well (Thengchaisri et al., 2014).

Study design

This study was a cross-sectional study design that can be potentially investigated data collected from a representative subset of population at a specific time period. In this study, disease is defined as obese condition in dogs and causes of diseases are factors of interest. Both of disease and causes were determined simultaneously. It was able to suggestive of a possible risk factors. This type of study design was good for disease having high prevalent cases, slow onset and not life-threatening disease- like obesity. Limitation of this study design was unable to confirm the causal relationship.

Table 2 Description of dog in 5 body condition score system

Score	Descriptions	Example
1	Ribs, Lumbar vertebrae, pelvic bones and all bony prominences evident from a distance. No discernible body fat. Obvious loss of muscle mass.	
2	Ribs easily palpated and may be visible with no palpable fat. Tops of lumbar vertebrae visible. Pelvic bones becoming prominent. Obvious waist.	
3	Ribs palpable without excess body fat covering. Waist observed behind ribs when viewed from above. Abdomen tucked up when viewed.	
4	Ribs palpable with difficulty; heavy fat cover. Noticeable fat deposits over lumbar area and base of tail. Waist absent or barely visible. Abdominal tuck may be present.	
5	Massive fat deposits over thorax, spine and base of tail. Waist and abdominal tuck absent. Fat deposits on neck and limbs. Obvious abdominal distention.	

*Adapted from Baldwin et al. (2010)

Bias in the study

Bias in an epidemiological study refers to tendency of a sample statistic to differ from the true population parameter. Throughout the cross-sectional study design, the bias can be presented at any phase of the study. In this study, we separated the potential sources of bias into 3 phases as suggested by (Pannucci and Wilkins, 2010).

1. **Pre-trial bias**

Selection bias

Ideally, the population needs to be specified at the beginning of the study. However, selection bias is still a particular problem of the cross-sectional study design because the disease and the causes have already occurred at the time individuals. If the sampling of individuals does not randomization of a population resulting in the unrepresentative sample for the population. This means the characteristics between participants selected for a study and those who are not, are differences. If this characteristic related with either the exposure or the outcome under implementation. Then, conclusion of the study may not be accurate.

2. **Bias during the trial**

Interviewer bias

This defined as the distortion of the outcome as a result from interviewer perceived the disease status of the patients. So, they search for the risk factors in case patients more concentrated than in control patients. This problem can be avoided if the interviewer is blinded to the disease status.

Information bias

Information bias is an error in measurement or outcome which can be happen with the interviewer/investigator. This means that patients who are assigned were in the wrong outcome category, as a result of incorrect estimation of the association between exposure and outcome. To avoid this error in cross-sectional study, and the investigators should be masked from the study hypothesis, exposure and disease status of individual at the time of study. Additionally, using well-constructed design and standardized questionnaires can reduce possible errors of the study.

Recall bias

Recall bias is existed when the exposure information and disease status are both noticed at time of the study. Especially, data was obtained by interviewing. The quality of data depends on the ability of patients to recognize the previous exposure. Most of the patients with disease can recall regarding the exposure in the past more accurately or completely compared with control patients. To minimize recall bias, the exposure data should be collected from the medical records or the patients are necessary to mask from the study hypothesis.

3. **Bias after the trial**

Confounding

Confounding occurs when a third variable is independently correlated (directly or inversely) with both exposure (independent variables) and outcome (dependent variable). It was not on the causal effect relationship but can mask an actual association being studied. If confounding factors are disregarded, bias may proceed in the conclusion of the study. In cross-sectional study, to control for confounding, true randomization in a study with large sample size, restriction, matching would be adopted. During analysis, multivariate regression analysis can be applied to control confounders during analysis.

Impact of dog obese condition on laboratory parameters

Laboratory parameters, for example, alkaline phosphatase, cholesterol, triglyceride, total protein, albumin, calcium, phosphorus, glucose and insulin were higher in overweight dogs than lean dogs (Yamka et al., 2006). Levels of serum creatinine, blood urea nitrogen, C-reactive protein, chloride and testosterone were lower in overweight dogs as well. Experiment from Diez et al. (2004) revealed that plasma urea, creatinine, ALP, AST, ALT, potassium, IGF-I, glucose and insulin was not affected by diet-controlled weight loss management. Lipid profiles including total cholesterol and triglyceride is elevated in obese dogs as well (Peña et al., 2008). The mechanisms of difference level in each parameter were unclear. According to lipid profiles level, some hypothesis mentioned that hypercholesterolemia and hypertriglyceridemia related with insulin-resistance condition in obese dogs. This is a result in dyslipidemia (Bailhache et al., 2003a; Bailhache et al., 2003b).

Dog obesity and thyroid metabolism

Thyroid hormones (T_3; triiodothyronine and T_4; thyroxine) are essential hormones functioning mainly on metabolism control and energy expenditure. The hormones are regulated via hypothalamic-pituitary-thyroid axis. Low thyroid levels induce hypothalamus to secrete Thyrotropin-Releasing Hormone (TRH). Consequently, TRH regulates secretion of Thyroid-stimulating hormone (TSH) at anterior pituitary gland to increase or decrease releasing of T_3 and T_4. Conversely, T_3 and T_4 have negative effect on thyroid hormone production so called negative feedback.

In obese dogs, few reports were noted about high levels of total T_3 and total T_4 in obese dogs compared with lean dogs (Daminet et al., 2003; Yamka et al., 2006) although Free T_4 did not differed (Daminet et al., 2003). Nevertheless, some previous study showed that no changes of total T_4 and free T_4 in diet-controlled for weight management (Diez et al., 2004). The effects of obesity on total T_3 and total T_4 have not been clearly defined both in dogs and human.

Chapter III
Materials and methods

Part I Study of prevalence and risk factors of canine obesity

Study design

A cross-sectional study design was conducted from 1January -31 August, 2016. The study of canine obesity (defined as disease-dependent variable) which can be caused by various factors (independent variables) in Thailand. The dogs with obesity were classified as cases of disease in the population and non-obese dogs were classified as controls of disease in the population. This study was conducted in all 6 regions of Thailand, Northern (Chiang Mai and Lampang), Northeastern (Khon Kaen and Nakhonratchasrima), Western (Kanchanaburi and Ratchaburi), Central Bangkok and Nakornpathom), Eastern (Chonburi and Chanthaburi) and Southern (Songkhla and Suratthani) part of Thailand (Figure 1). The data collection and dog body shape assessment were performed by a veterinarian throughout the study. The provinces were assigned based on the number of human population. The animal hospitals for each province were selected by convenience sampling.

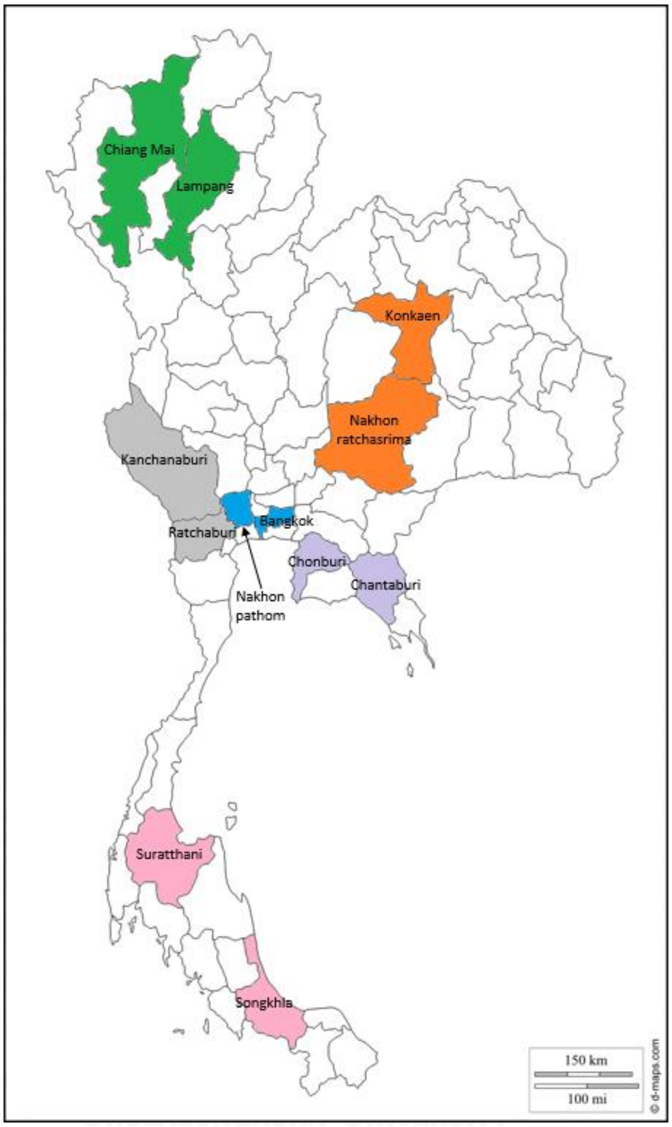


Figure 1 Graphical distribution of data collection from 6 regions of Thailand.

Participants

Owners and dogs were included into the study. The inclusion criteria were dogs over one years with any breed, sex and health status. The exclusion criteria was pregnant dogs. The sample size was 400 dogs per region. During the period of data collection, all dogs visited the animal hospitals were enrolled in this study, except at The Small Animal Hospital, Chulalongkorn University. According to large numbers of patients visiting Small Animal Hospital, Chulalongkorn University, the assessor was not able to assess all visited dogs. Then, the assessor was labeled the key chairs in department of medicine. The dogs, which owners sat on those chairs, were participated this study.

Sample size

The sample size per region was estimated by the formula for a single population proportion with 95% confidence level and 5% margin of error. The estimated population of dogs in Thailand equal to 100,000.

Questionnaires

The preliminary tests of the questionnaire were conducted with a group of 20 owners in two animal hospitals in Nakhonratchasrima and at Small Animal Hospital, Chulalongkorn University, Bangkok, Thailand. A questionnaire was well designed to collect dog information. Avoiding the bias from respondents, the owners were interviewed with structured criteria and the same set of questions in the same order. Questions were specific, clear and not leading questions. Then, the questionnaire was adjusted and launched to collect the data in the selected samples. The owners were interviewed following the questions in the questionnaire.

The dog owners were interviewed dog characteristics which can be predictor variables. These questionnaires and protocols were approved by the Ethic Committee for the Human and/or Animal Experimentation, Faculty of Veterinary Science and the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University (COA No.241/2558).

Predictor variables

Age

Age was recorded as a continuous variable. The rest of year was round up to 1 year. Age of dogs was then categorized into 3 groups as shown in Table 3.

Table 3 Age categories in this study

Predictor variable	**Categories**
Age	1-2 years 3-8 years >8 years

Breed

Thirty-nine breeds were grouped into 3 body size categories referred from AKC (American Kennel Club) and FCI (Federation Cynologique International for dogs worldwide), including, small, medium and large breed (Table 4).

Table 4 Classification of dog body size and breeds

Predictor variable	Categories
Breed*	Small breed:
	Chihuahua
	Dachshund
	Fox Terrier
	French Bulldog
	Jack Russell Terrier
	Lhasa Apso
	Maltese
	Miniature Pinscher
	Mixed breed dog (small size)
	Pekingese
	Pomeranian
	Poodle
	Pug
	Schnauzer
	Shih Tzu
	West Highland White Terrier
	Yorkshire Terrier
	Medium breed:
	Bangkaew
	Beagle
	Border Collie
	Bull Terrier
	Bulldog
	Cocker spaniel
	Welsh Corgi
	Dalmatian

Predictor variable	Categories
	Doberman Pinscher
	Mixed breed dog (medium size)
	Pitbull
	Rottweiler
	Shetland Sheepdog
	Siberian Husky
	Spitz
	Thai Ridgeback
	Large breed:
	Alaskan malamute
	German Shepherd
	Golden Retriever
	Labrador Retriever
	Mixed breed dog (large size)
	Saint Bernard

Gender and Neuter status

Dogs were classified into 2 genders (male dogs or female dogs) and 2 neuter status (intact dogs or neutered dogs).

Food type

Food types were classified as 6 types in the questionnaires, including, dry food, canned food, pouched food, home prepared food, table scraps and others. However, owner fed their dogs with variety of food type in Thailand. The foods that fed to the dog at least once daily were take accountable for inclusion. In this study, food types were grouped into 3 categories as shown in Table 5.

Table 5 Categories of food type

Predictor variable	Food category in analysis
Food type	Commercial food: Only dry food Only pouched food Only canned food Homemade food: Home prepared diet Combined food: (Commercial/ Home-prepared/Table scraps)

Frequency of feeding

Frequency of feeding were divided into 4 groups; once daily, twice a day, three times a day and always available.

Feeding snacks or treats

Feeding snacks or treats were classified into 5 categories; frequently to rarely once daily, twice to three times a week, once weekly, once monthly or less than one time per month.

Living style

Living style were categorized into indoor or free-roaming.

Overweight or obese dogs or cats in the same household

The result was recorded as a dichotomous variable (Yes or No).

Concurrent diseases

Existing diseases of dogs were noted as skin diseases, blood parasites, gastrointestinal diseases, cardiovascular diseases, musculoskeletal diseases, Liver diseases, Kidney diseases and others. A dog could be assigned into more than 1 category. Finally, the disease condition was classified as healthy, single concurrent disease and more than one diseases.

Owner body mass index

The weight and height of the dog owners were recorded. Then, the body mass index (BMI) of owners were calculated using formula shown below.

$$BMI = weight\ (kg) / [height\ (m)]^2$$

Finally, the owner BMI was categorized into 4 groups as shown in Table 6.

Table 6 Weight category and BMI of owner

Weight category	BMI (kg/m^2)
Underweight	<18.5
Normal	18.5-24.9
Overweight	25-29.9
Obesity	>30

Part II Investigation of owner's misperception

Study design

According to the survey in part I, all participants were included in this part. All dogs were assessed by veterinarian using 5-scale body condition score. Owners evaluated body shape of dogs based on their own judgment as excessively thin (score 1), thin (score 2), normal (score 3), overweight (score 4), or obese (score 5) without any advice. Both two assessments were matched to find out the misperception of owners (Figure 2). In case of dogs with multiple owners, the owners who are the major responsible for taking care of dog was enrolled.

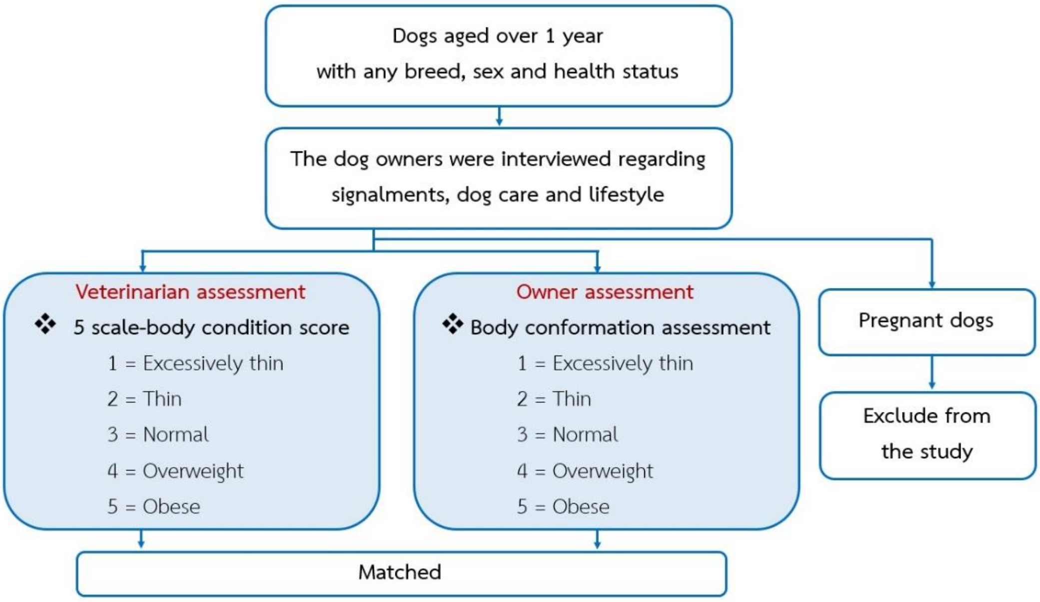


Figure 2 Inclusion criteria of this study

Avoiding or minimizing the bias in part I and II

1. **Pre-trial bias**

Selection bias

To make the sample being a good representative for all dog population in Thailand, the sampling was distributed to 6 regions of Thailand.

2. **Bias during the trial**

Interviewer bias

This bias was minimized by assigned only one veterinarian to interview all participants. The interview was performed using the same questionnaire and the same order of interviewing and do not concentrate with risk factors.

Information bias

To reduce the information bias, only one veterinarian was assigned to evaluate all dogs throughout the study. All dogs were classified base on the same judgement.

Recall bias

An owner who had obese dogs often recalls their dog factors that may cause of obesity. However, owner with non-obese dogs may not notice those factors which may relate with obesity. The good question with choices can help owners to remind the factors. In addition, the best way to minimize recall bias by masking the owners from the study hypothesis. Anyway, this bias cannot be avoided or get rid completely, and this investigator must always be kept in mind its existence.

3. **Bias after the trial**

Confounding

To reduce the effects from the confounder, this study was conducted with large sample size (n=2,401) which calculated from one sample proportion. We estimated 100,000 dogs in the formula which it was a large sample estimation. Furthermore, the multiple logistic regression was performed to figure out the magnitude of risk for all potential risk factors after adjusted effects from confounders.

Statistical analysis

Part I and part II Prevalence, perception and risk factors of canine obesity in Thailand

In part I, all potential risk factors were grouped into categories as mentioned in topic predictor variables. The magnitude of association between risk factors and obesity was generated by a univariable logistic regression. The univariate analysis were used to select the highly associated variables with dog obesity prior to perform multivariable analysis. Then, the multicollinearity test was performed by Kendal-tau B. The significant main effects (p-value <0.2) were entered into the model including their interaction terms. The likelihood ratio was calculate to include variables in the main effects and to drop other variables or interaction without significant (p-value >0.05) by backward elimination. The fit of the model was performed by Hosmer-Lemeshow goodness-of-fit test. To control confounders, the multivariable analysis was performed using multiple logistic regression. The odd ratio (OR) in the final model can estimate the increased or decreased risk for obesity from independent factors.

Part II aimed to evaluate misperception of owners. The comparison between owner assessment and veterinarian assessment was analyzed by marginal homogeinity test using Stuart-Maxwell test. This test can indicate the difference between classification of dogs by owners and veterinarian. All statistical analyses were analyzed using the software of SPSS Statistics version 22.0 program with p-value <0.05.

Part III Determination of the relationship between canine obesity and laboratory parameters

Inclusion and exclusion criteria in this study were shown in Figure 3. Dogs were included randomly from the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University. All dogs must be assessed as clinical healthy through a physical examination and must not have any previous diseases, including gastroenteropathy, liver disease and trauma. Then, the participating healthy dogs are divided into 2 groups, 50 obese dogs (body condition score 4 and 5) and 50 non-obese dogs (body condition score 2 and 3). Four milliliters of blood samples were collected from either cephalic vein or lateral saphenous vein. Two milliliters of blood samples were added into EDTA anti-coagulant (Ethylenediaminutesetetraacetic acid) and heparin tubes. Blood with EDTA was measured by automated CELL-DYN 3700 analyzer

(Abbott Laboratories, UK). The clinically healthy dogs were confirmed as healthy by complete blood count results that were within normal ranges. The plasma was separated by centrifugation at RCF 1000×g for 10 minutes and was stored at -20°C for later measurement for blood chemistry (ALT, ALP, total protein, albumin, cholesterol, and triglyceride) by ILab650 chemistry analyzer (Diamond Diagnostics, USA). The thyroid level (Total T_4) was analyzed using an AIA-360 enzyme immunoassay analyzer (TOSOH Corporation, Japan).

Statistical analysis

All laboratory profiles were recorded as continuous variables. To assess that data was normally distributed, test of normality was performed by Shapiro-Wilk test. The difference between laboratory parameter levels in obese and non-obese dogs was determined. Normal distributed data was used independent T-test and non-normally distributed data was analyzed by Mann-Whitney U test. Statistical significance was considered at p-value <0.05. All statistical analyses were conducted using the software of SPSS Statistics version 22.0 program.

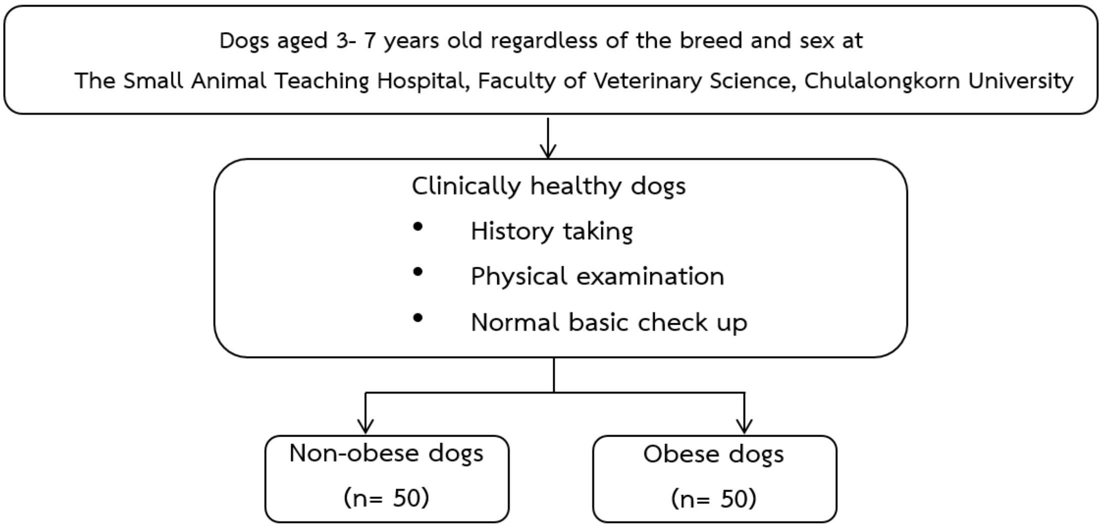


Figure 3 Inclusion criteria for selecting healthy obese and non-obese dogs.

Chapter IV
Results

Part I Study of prevalence and risk factors of canine obesity in Thailand

Body condition score (BCS) assessed by veterinarian

In total, of 2,401 dogs examined, the prevalence of canine overweight and obesity equals to 42.94%. The BCS mean was 3.49 $\pm$ 0.021.

Descriptive statistics of the predictor variables

Age

The mean age was 5.67 $\pm$ 0.086 (median 5 years), ranging from 1 to 22 years old. The sample size of old dogs (≥14 years old) was small as a result of unreliable obesity rate. The obesity rate of each age was shown in Table 7. Trends of obesity gradually increased up to 1 year and dropped at 10 years old dogs (Figure 4). The high proportion of obesity was found in middle-age dogs (age range 3-14 years old) with the highest proportion at 9 years old dogs. One year-old dogs had low proportion of obesity compared with middle-age dogs.

Table 7 The distribution of ages and dog weight categories of the 2,401 dogs

Age (years)	No of dogs N (%)	Dog weight categories (%)	
		Non-obese dogs (BCS 1-3)	Obese dogs (BCS 4-5)
1	485 (20.20)	75.87	24.13
2	259 (10.79)	62.55	37.45
3	232 (9.66)	60.34	39.66
4	167 (6.96)	56.28	43.72
5	204 (8.50)	50.98	49.02
6	130 (5.41)	41.54	58.46
7	185 (7.71)	44.33	55.67
8	159 (6.62)	44.65	55.35
9	82 (3.42)	41.47	58.53
10	154 (6.41)	50.65	49.35
11	65 (2.71)	47.70	52.30
12	76 (3.17)	50.00	50.00
13	59 (2.46)	52.54	47.46
14	55 (2.29)	58.18	41.82
15	43 (1.79)	76.74	23.26
16	25 (1.04)	24.00	76.00
17	6 (0.25)	50.00	50.00
18	9 (0.37)	66.66	33.33
19	1 (0.04)	100.00	0
20	4 (0.17)	50.00	50.00
21	0 (0)	0	0
22	1 (0.04)	0	100.00
Total	2,401 (100)	57.06	42.94

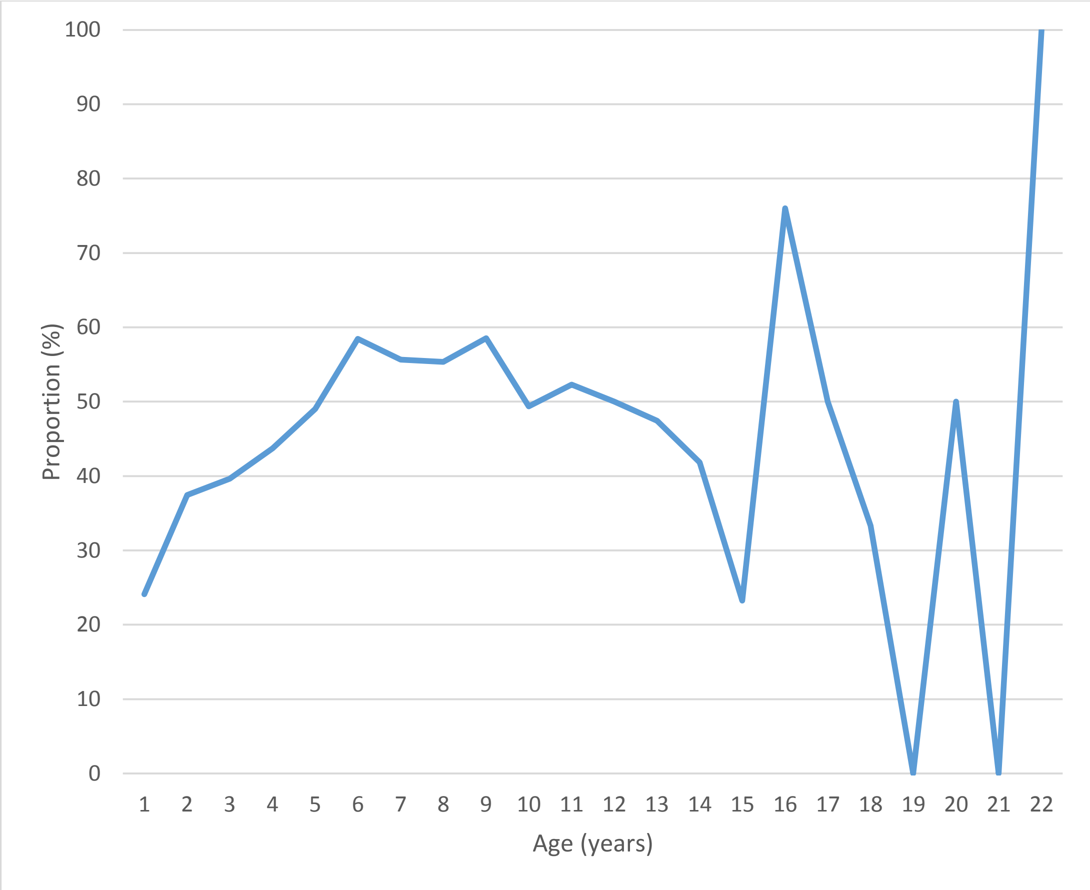


Figure 4 The trend of obesity proportion and age (years) of the 2,401 dogs

Gender and neuter status

Of 2,401 dogs, the proportion of overweight and obesity on each gender and neuter status was shown (Figure 5). The number of male dogs and female dogs were nearly equal. The ratio of obese/non-obese dogs in intact male dogs and intact female dogs was equal. The ratio of obese/non-obese dogs in castrated male dogs was higher than female neutered dogs. Obviously, castrated and neutered dogs had the high obese/non-obese dogs ratio but intact dogs had the low obese/non-obese dogs ratio.

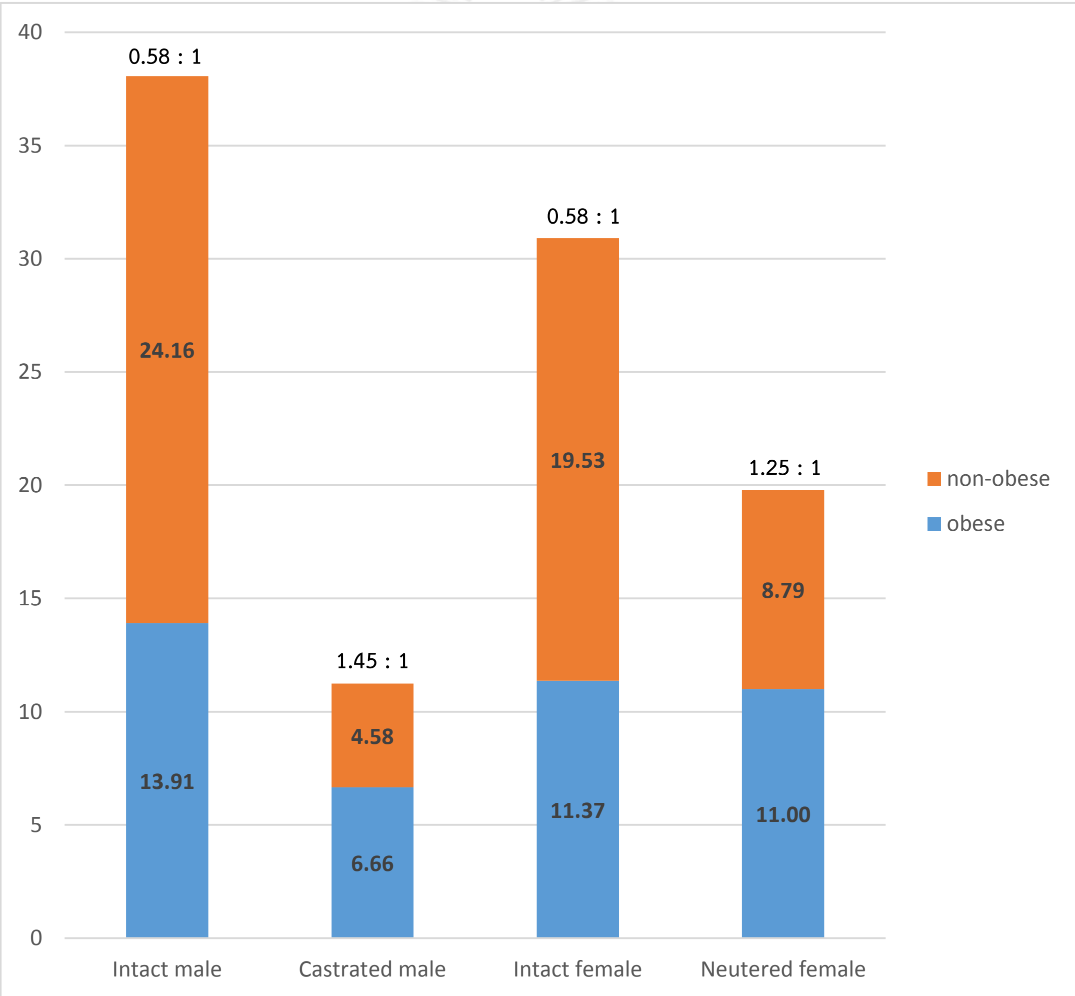


Figure 5 The proportion of overweight and obese dogs in each gender and neuter status of the 2,401 dogs

Breeds

Top 15 breeds which had the highest number of dogs in this study were shown in Table 8. Percentage of obese dogs within breed were calculated. Some certain breed, such as Beagle, Pug, Labrador Retriever, Golden Retriever, Shih Tzu, Mixed breed dogs (small size), Mixed breed dog (medium size), Bangkaew, Poodle had high proportion of obese dogs. Compared number of obese dogs with the total number of dogs, Mixed breed dogs (medium size) had the highest percentage of obese dogs.

Table 8 Top 15 breeds with the highest prevalence of canine obesity

Breeds (n)	No of dogs N (%)	Prevalence of canine obesity (%)
Beagle (51)	78.43	1.67
Pug (56)	73.21	1.71
Labrador Retriever (44)	61.36	1.12
Golden Retriever (63)	55.56	1.46
Shih Tzu (264)	46.21	5.08
Mixed breed dog (small size) (214)	44.39	3.96
Mixed breed dog (medium size) (662)	42.30	11.66
Bangkaew (87)	41.38	1.50
Poodle (243)	40.74	4.12
French bulldog (39)	38.46	0.62
Pomeranian (193)	34.72	2.79
Yorkshire Terrier (31)	32.26	0.42
Mixed breed dog (large size) (35)	28.57	0.42
Chihuahua (168)	25.00	1.75
Siberian Husky (67)	20.90	0.58

Food type

Food type is one of the major causes of high obesity rates. The proportion of feeding with single food type or mixed food type was shown in Table 9. Most of owners fed their dogs with several types of food (67.97%), for example, both commercial and non-commercial food.

Table 9 Proportion of feeding with single food type or mixed food types

Predictor variable	No of dogs (N)	Proportion (%)
Commercial food only:	**541**	**22.53**
Only Dry food	519	21.62
Only Pouched food	10	0.42
Only Canned food	12	0.5
Home prepared diet only:	**228**	**9.50**
Combined food:	**1,632**	**67.97**
(Commercial/ Home prepared/Table scraps)		

Frequency of feeding

Most owners fed their dogs twice daily. Owners of small dogs were more likely to feed their dogs three time per day and always have food available. However, the results showed that dogs fed once daily had the highest ratio of obese/non-obese dogs while other schedule feeding times had the low ratio. (Figure 6).

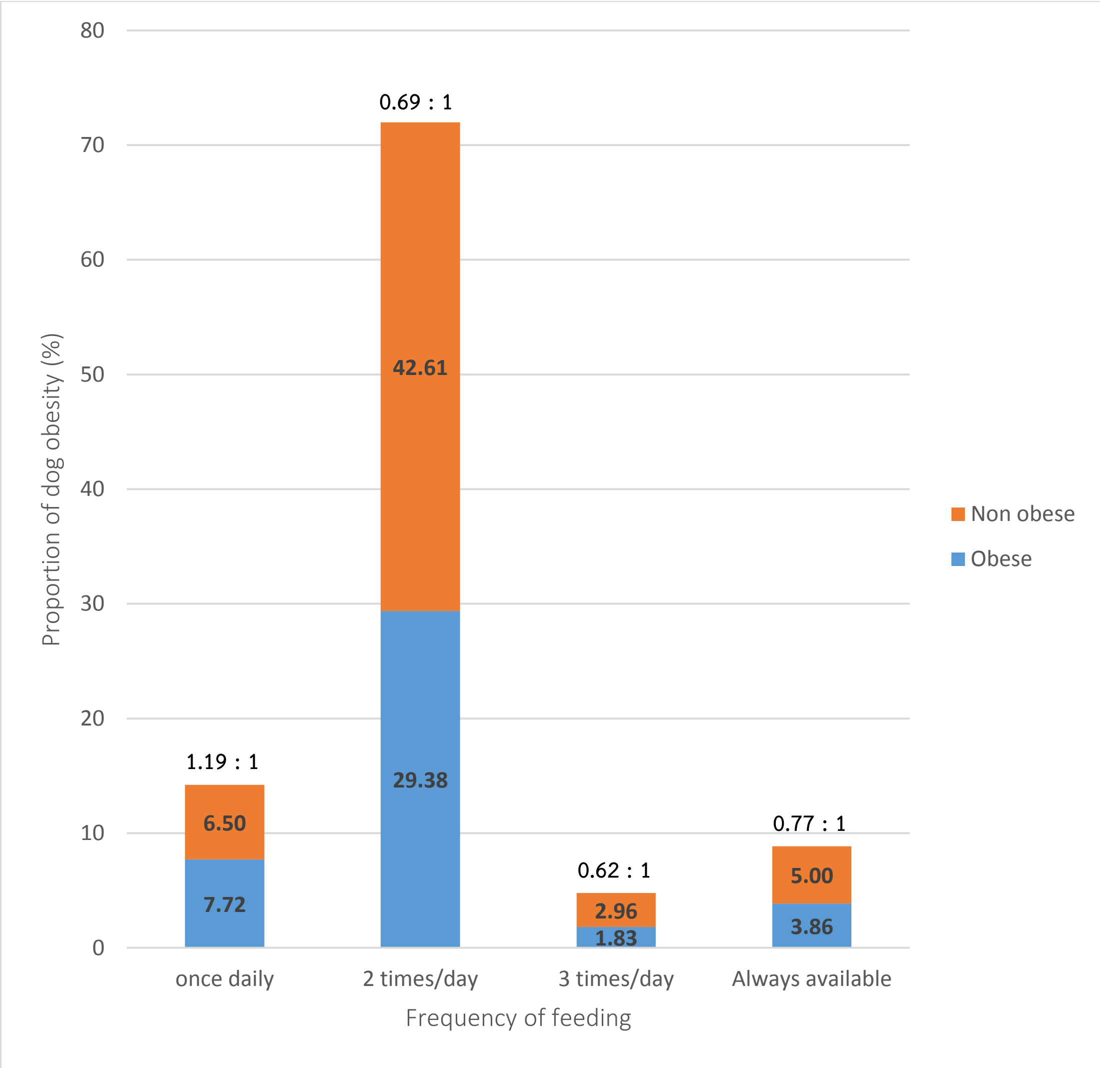


Figure 6 The proportion of frequency of feeding and dog obesity of 2,401 dogs

Snacking

One-third of the dogs were not fed with snacks. Dogs given snack once daily had the highest obesity rate while dogs having no snack had the lowest obesity rate (Figure 7).

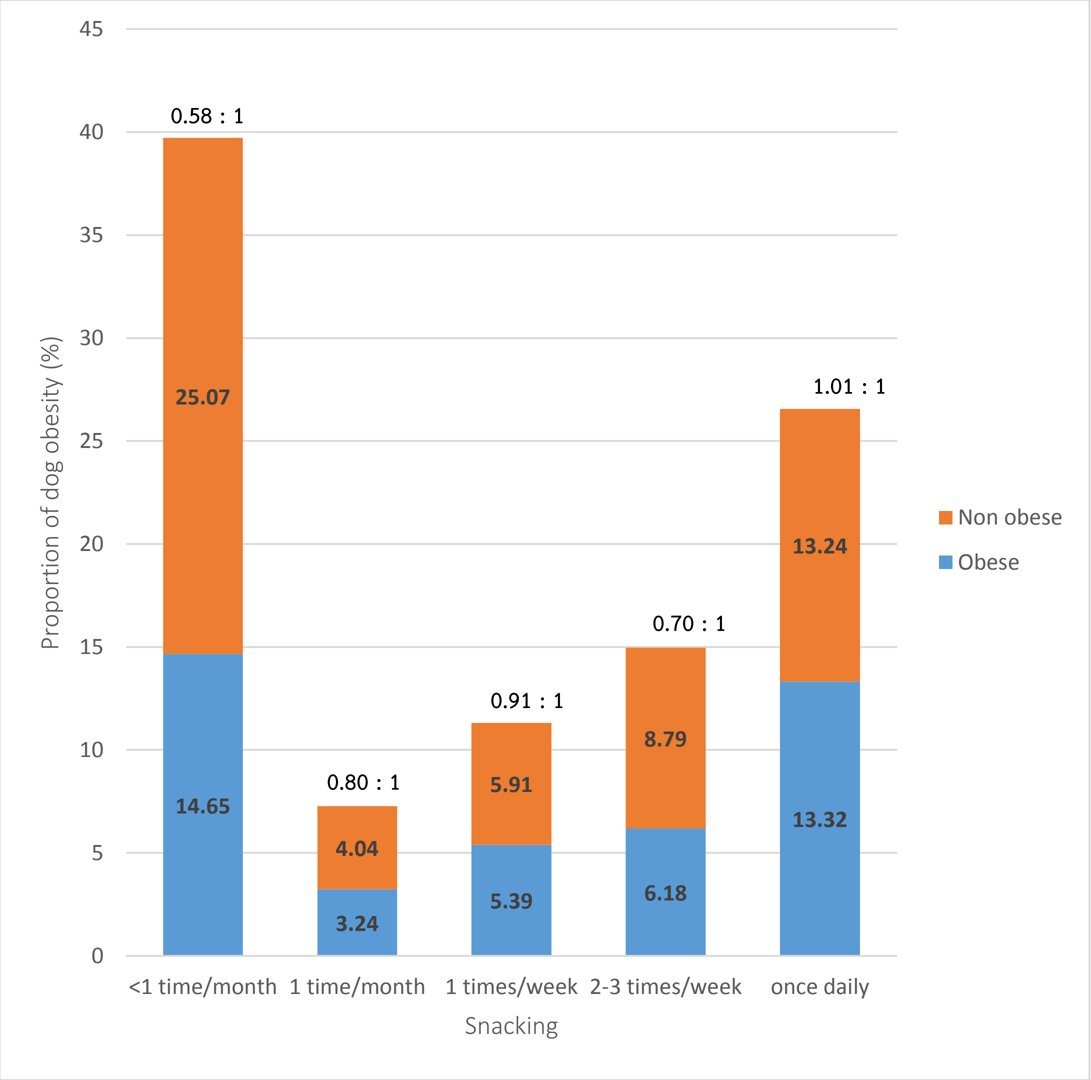


Figure 7 The proportion of dog obesity and snacking of 2,401 dogs

Obese dogs in the same household

One-third of the dogs in this study had other obese dogs in the same household. Dogs having other obese dogs in the same household had higher obesity rate when compared with dogs having no obese dogs in the same household (Figure 8).

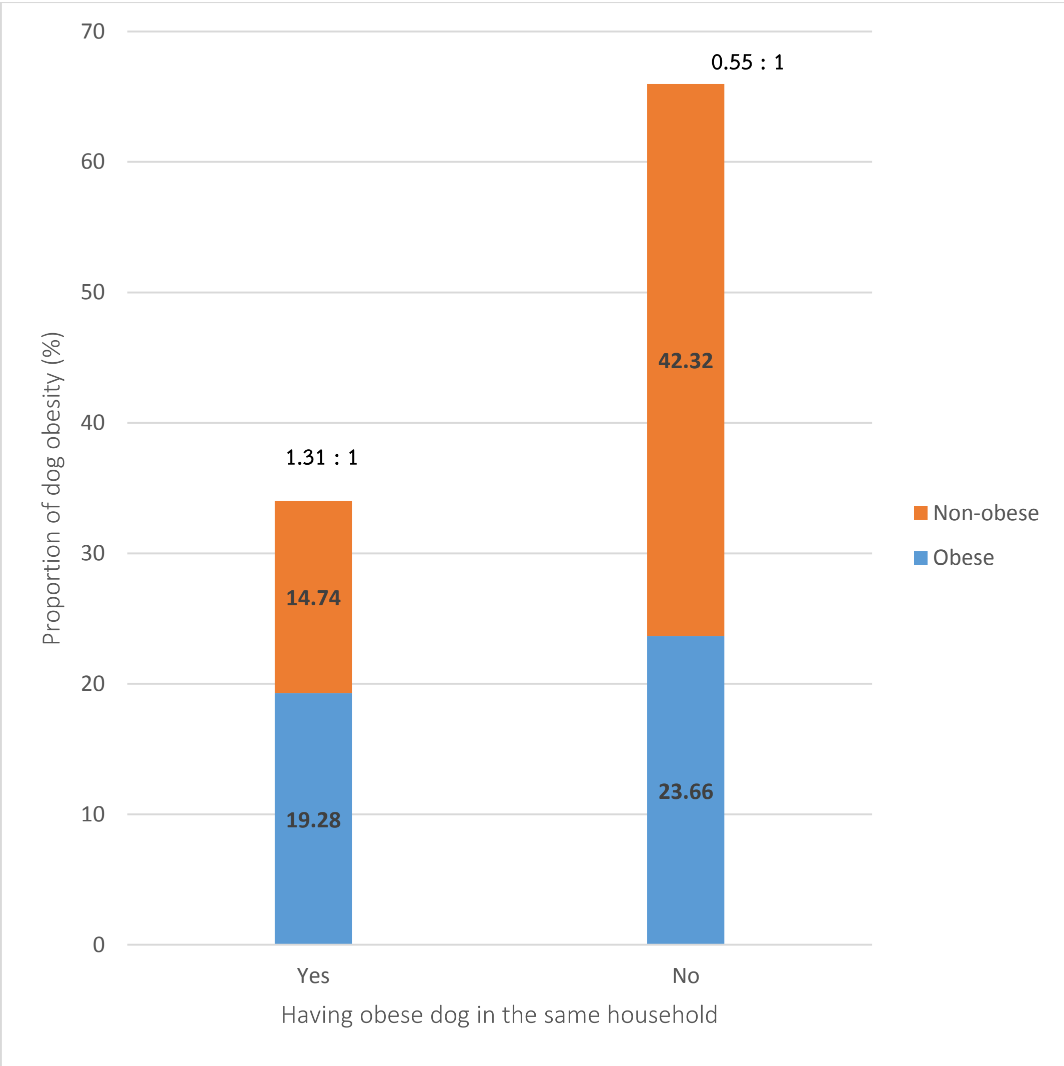


Figure 8 The proportion of obese dogs and having other obese dogs in the same household

Obese cats in the same household

A few dogs had obese cats in the same household. Dogs had the equal ratio of obese/non-obese dogs regardless of having or not having other obese cats in the same household (Figure 9).

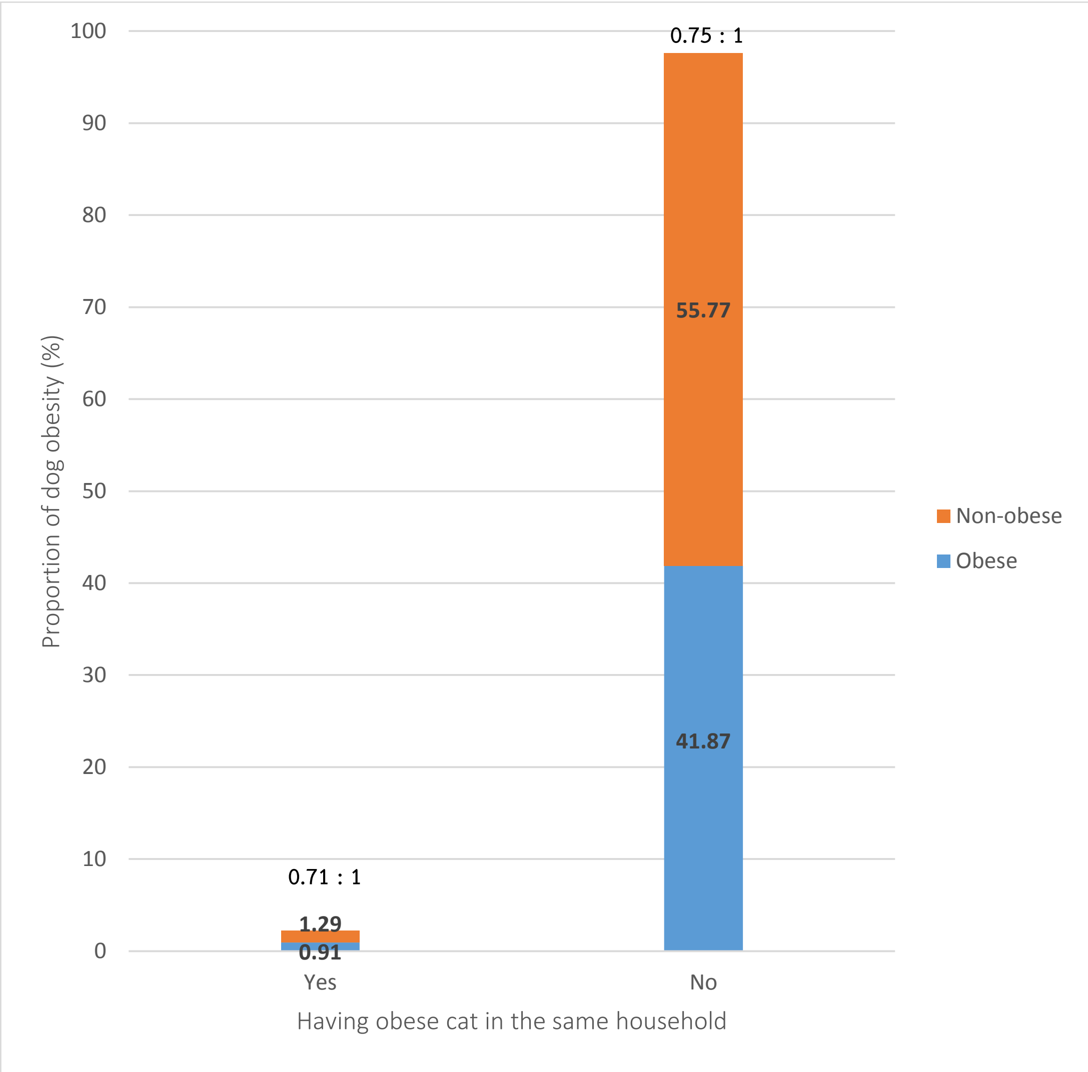


Figure 9 The proportion of obese dogs and having obese cats in the same household

Living style of the dogs

Most of the dogs in this study were kept indoor. Indoor dogs had higher proportion of obese dogs when compared with free-roaming dogs (Figure 10).

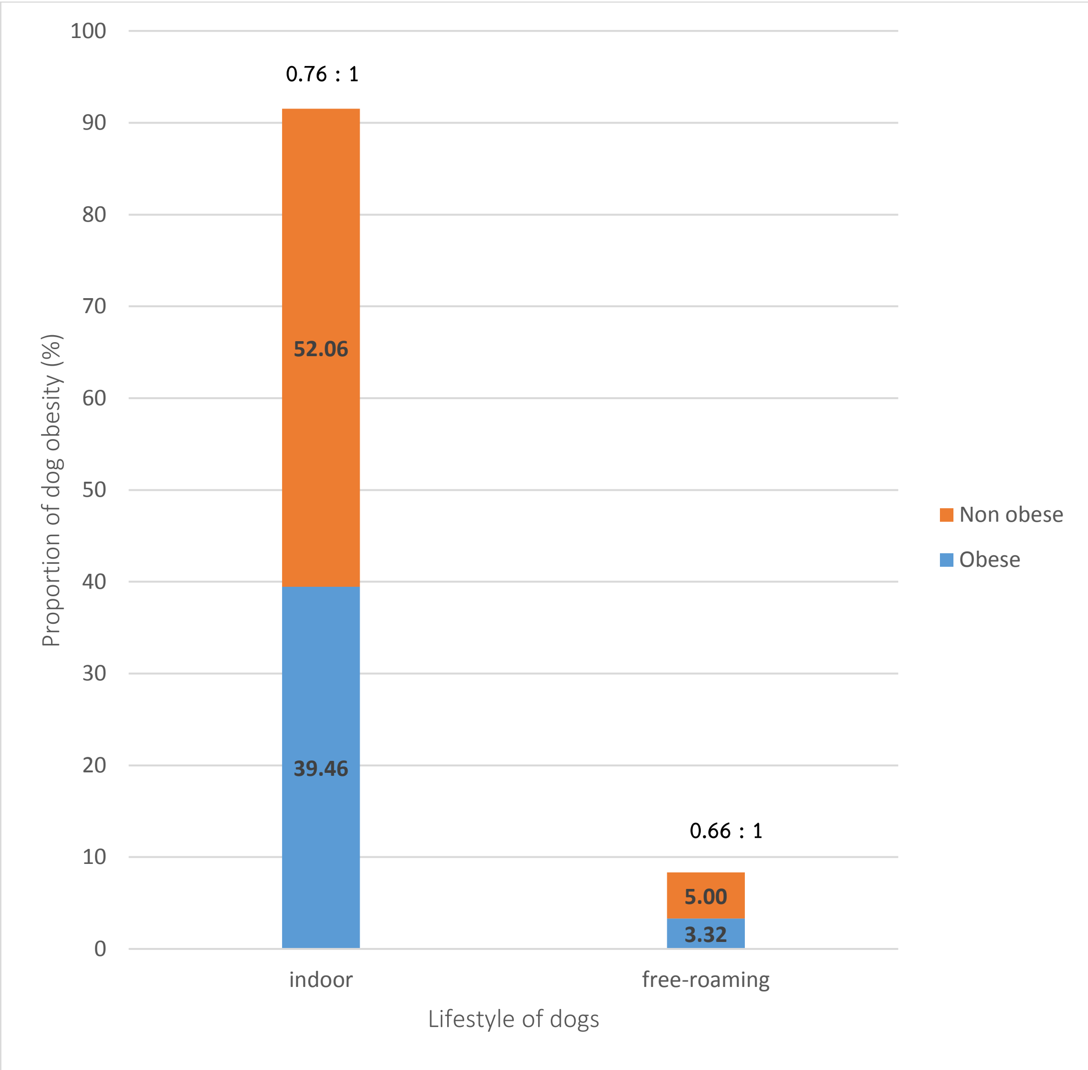


Figure 10 The proportion of dog obesity in each living style of the 2,401 dogs

Concurrent diseases

In this study, half of the dogs were considered as healthy by owners. Most of diseases which classified as others were tumor (n=77), eye problems (n=61) and calculi (n=47). The top three concurrent diseases are others, blood parasites and skin diseases. The proportions in each dog weight categories and concurrent disease were shown in Table 10. Dogs with kidney diseases, skin diseases, heart and vascular diseases and musculoskeletal diseases had the high proportion of obese dogs. The dogs were classified into 3 groups based on health status, healthy (n=1,413), having single concurrent disease (n=772) and having more than one concurrent diseases (n=216). The majority of dogs having more than one diseases were dogs with skin diseases and blood parasites (n=24). The obese proportion and health status was shown in Figure 11. Interestingly, dogs with more than one diseases are tend to be obese.

Table 10 The proportion of healthy dogs and dogs with concurrent diseases

Concurrent diseases	Dog weight categories (%)		N (%)
	Non-obese dogs	Obese dogs	
Healthy	60.79	39.21	1,413 (58.85)
Skin diseases	49.79	54.21	273 (11.37)
Blood parasites	55.99	44.01	309 (12.87)
Gastrointestinal diseases	75.00	25.00	8 (0.33)
Heart and vascular diseases	48.98	51.02	98 (4.08)
Musculoskeletal diseases	50.00	50.00	20 (0.83)
Liver diseases	53.66	46.34	82 (3.42)
Kidney diseases	35.90	64.10	39 (1.62)
Others	49.20	50.80	435 (18.12)
Total	57.06	42.94	

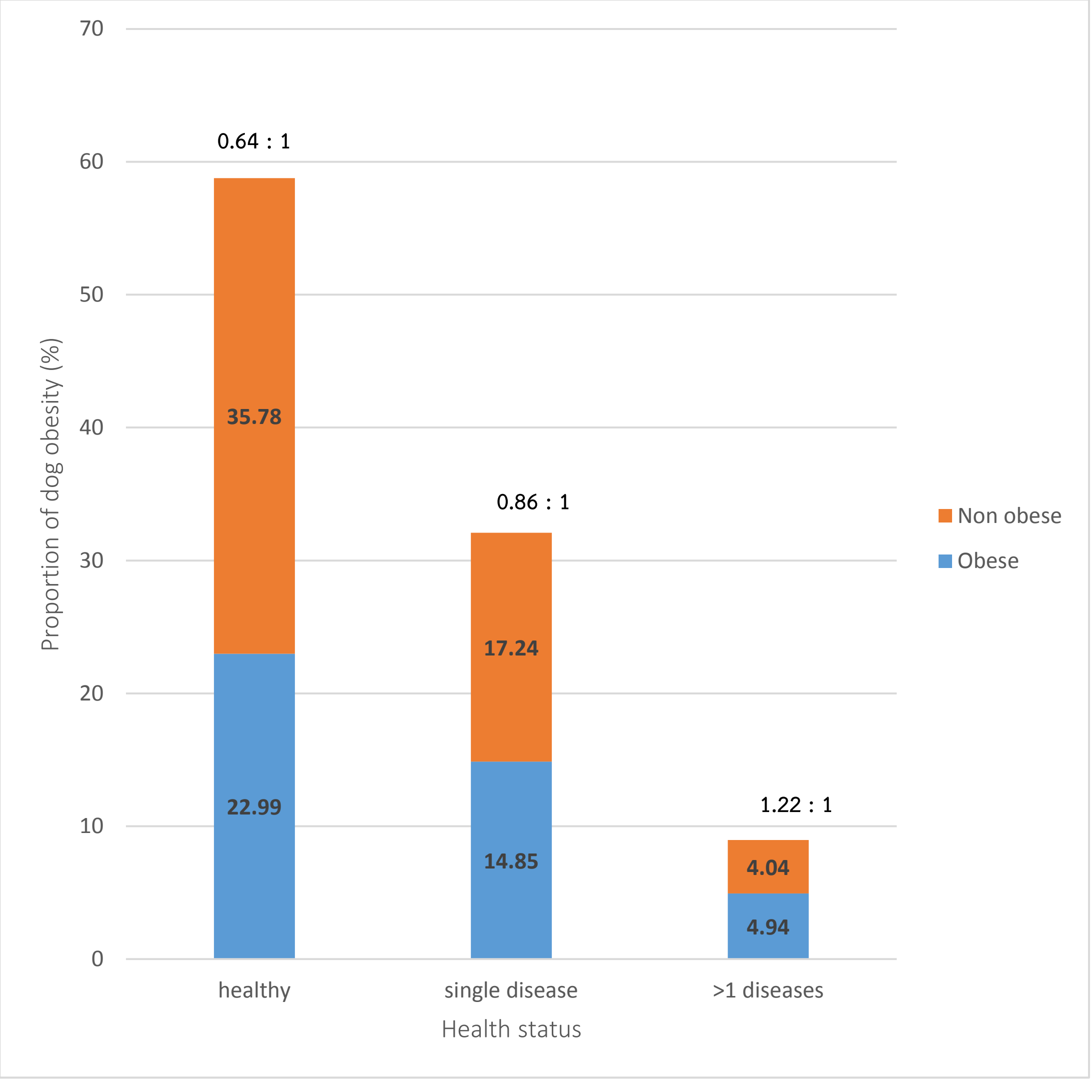


Figure 11 The proportion of obese dog and health status

Body mass index of the owners

The average of body mass index from owners of 2,401 dogs was 22.53±3.92. Most of the owners had normal BMI. The overall trend of BMI was shown in Figure 12. The proportion of each BMI categories of owners and proportion of obese dogs was presented in Figure 13. Most of the owners had normal BMI.

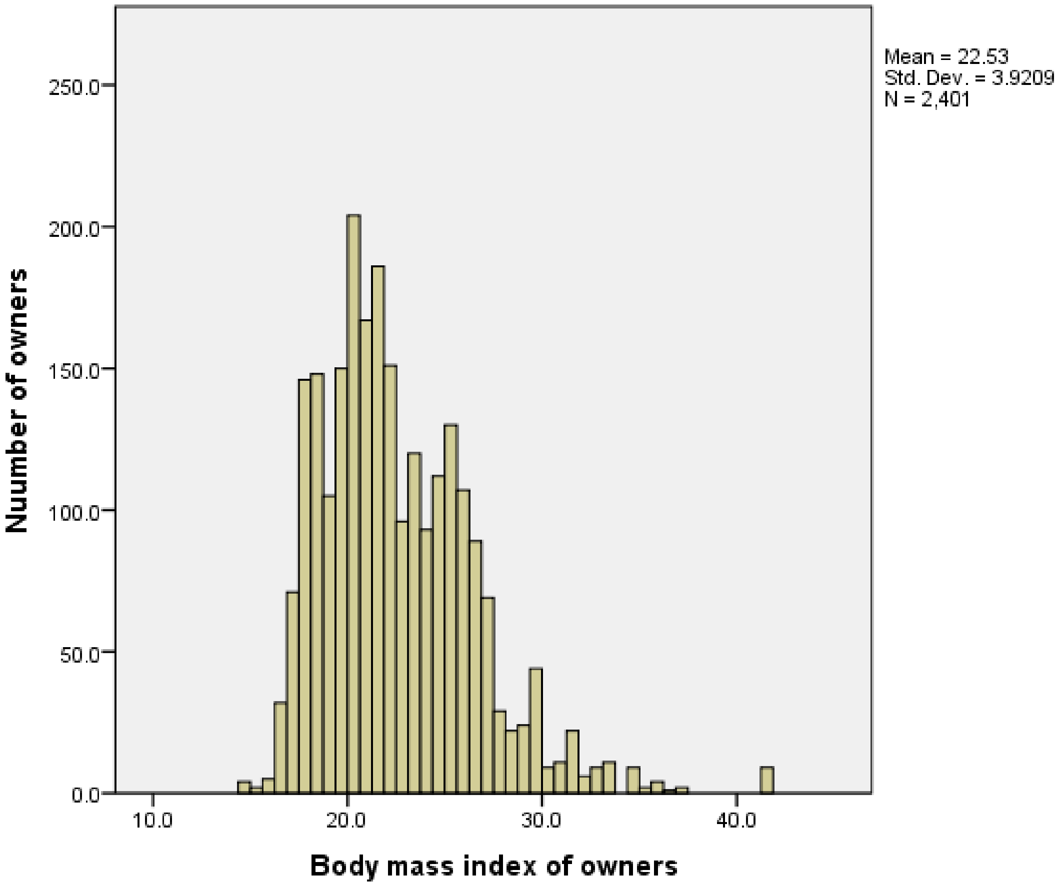


Figure 12 Trend of BMI of dog owners in Thailand

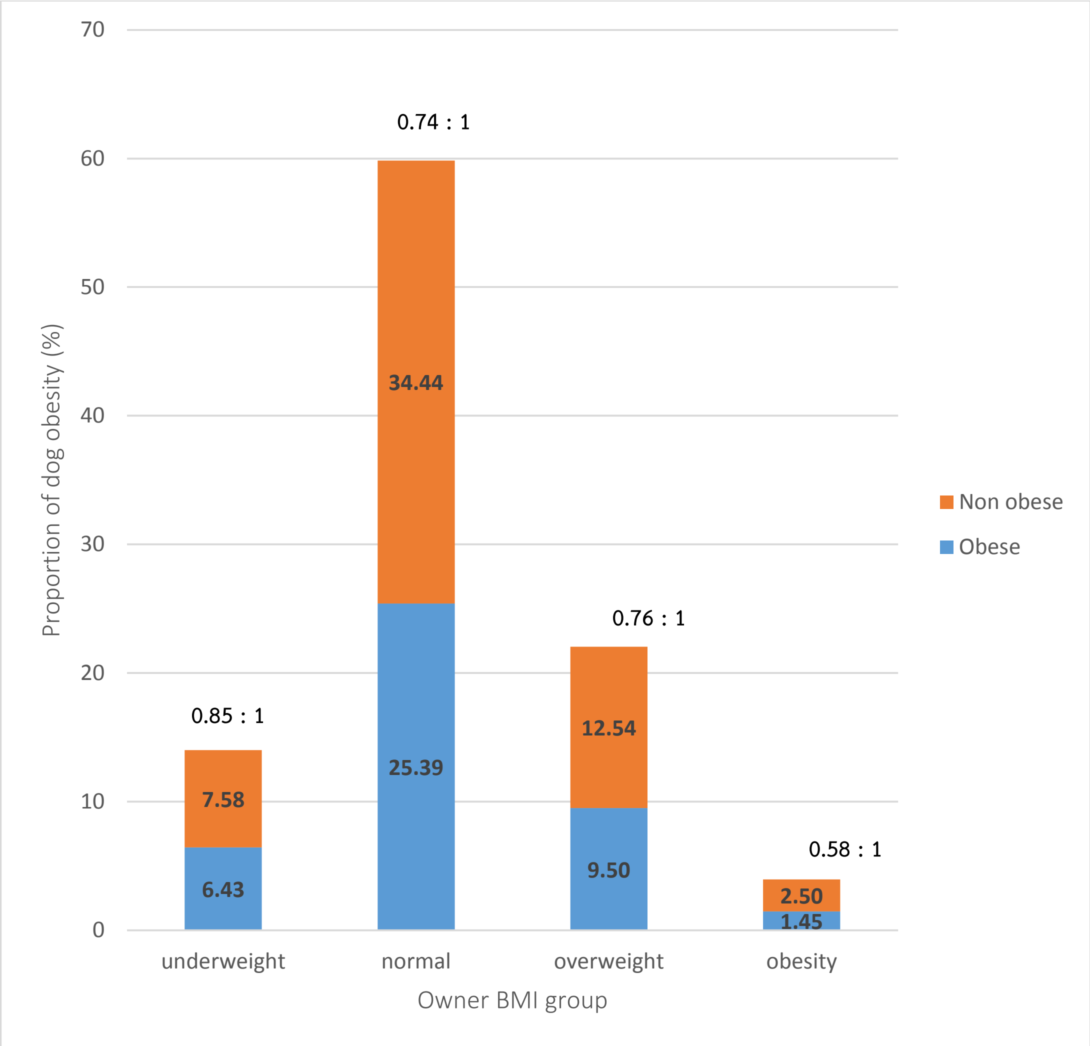


Figure 13 The BMI categories of owners and proportion of obese dogs

The univariate analysis

The results of individual variable and canine obesity were analyzed using binary logistic regression (Table 11). Age, breed, neuter status, frequency of feeding, feeding snacks or treats, having obese dogs in the same household and concurrent diseases were statistically significant at p-value <0.0001. Breed and food type were demonstrated to be related with dog obesity (p-value= 0.1 and 0.004, respectively). Other variables were not statistically significant with canine obesity.

Table 11 Univariate logistic regression analysis between predictors and canine obesity

Risk factors	β (S.E.)	95% CI for EXP (β)	p-value	OR
Age				
1-2 years	Ref			(1)
3-8 years	0.88 (0.10)	1.98-2.95	<0.0001	2.42
>8 years	0.87 (0.12)	1.91-3.00	<0.0001	2.39
Breed				
Small breed	Ref			(1)
Medium breed	0.14 (0.09)	0.97-1.36	0.103	1.15
Large breed	0.29 (0.17)	0.96-1.85	0.083	1.33
Neuter status				
Intact	Ref			(1)
Neutered	0.83 (0.09)	1.91-2.72	<0.0001	2.28
Food type				
Commercial food only	Ref			(1)
Homemade diet only	0.51 (0.16)	1.22-2.28	0.001	1.67
Combined food only	0.24 (0.10)	1.04-1.54	0.021	1.27
Frequency of feeding				
Once daily	Ref			(1)
Twice per day	-0.54 (0.12)	0.46-0.73	<0.0001	0.58
Three times per day	-0.65 (0.22)	0.34-0.80	0.003	0.52
Always available	-0.43 (0.18)	0.46-0.93	0.014	0.65
Snacking				
Once daily	Ref			(1)
Twice to three times week	-0.36 (0.13)	0.54-0.91	0.007	0.70
Once weekly	-0.10 (0.14)	0.68-1.21	0.500	0.91
Once monthly	-0.23 (0.17)	0.57-1.12	0.185	0.80
Less than one time per month	-0.54 (0.10)	0.47-0.71	<0.0001	0.58
Having obese dogs in the same household				
No	Ref			(1)
Yes	0.85 (0.09)	1.97-2.78	<0.0001	2.34
Concurrent diseases				
Healthy	Ref			(1)
Single concurrent disease	0.29 (0.09)	1.12-1.60	0.001	1.34
More than one diseases	0.64 (0.15)	1.43-2.54	<0.0001	1.90

The multivariate logistic regression analysis

Significant predictors from univariate analysis including age, breed, neuter status, food type, frequency of feeding, feeding snacks or treats and having obese dogs in the same household were added in the final logistic regression model. The Hosmer-Lemeshow goodness-of-fit was not significant (p-value= 0.172). From multivariable logistic regression, the risk of canine obesity was increased if the dogs had age 3-8 year (OR= 1.98), neutered (OR=1.63), fed with snacks or treats once daily (OR= 1.47) and having obese dogs in the same household (OR= 2.37) (Table 12).

Table 12 Risk factors of canine obesity analyzed by multivariable logistic regression

Risk factors	β (S.E.)	95% CI for EXP (β)	p-value	OR
Age				
3-8 years	0.68 (0.11)	1.61-2.44	<0.0001	1.98
>8 years	0.59 (0.13)	1.41-2.30	<0.0001	1.80
Neuter status				
Neutered	0.49 (0.17)	1.18-2.27	0.003	1.63
Feeding snacks or treats				
Once monthly	-0.05 (0.22)	0.62-1.48	0.925	0.96
Once weekly	0.28 (0.18)	0.93-1.86	0.068	1.32
Twice to three per week	-0.12 (0.16)	0.65-1.22	0.521	0.89
Once daily	0.38 (0.13)	1.13-1.91	0.002	1.47
Having obese dogs in the same household				
Yes	0.86 (0.12)	1.89-2.97	<0.0001	2.37

*-2Log Likelihood = 3047.10

Part II Investigation of owner's misperception

Body Conformation (BC) assessed by owners

The obesity rate assessed by owner was 32.90%. The mean BC was 3.32 ± 0.939. Comparison between veterinarian assessment (Body Condition Score) and owner assessment (Body Conformation) was shown in Figure 14. The prevalence of overweight and obese dogs (BCS 4 and 5) assessed by veterinarian were higher than prevalence from owner assessments while the prevalence of normal dogs (BCS 3) assessed by veterinarian was lower than the result from owner assessments.

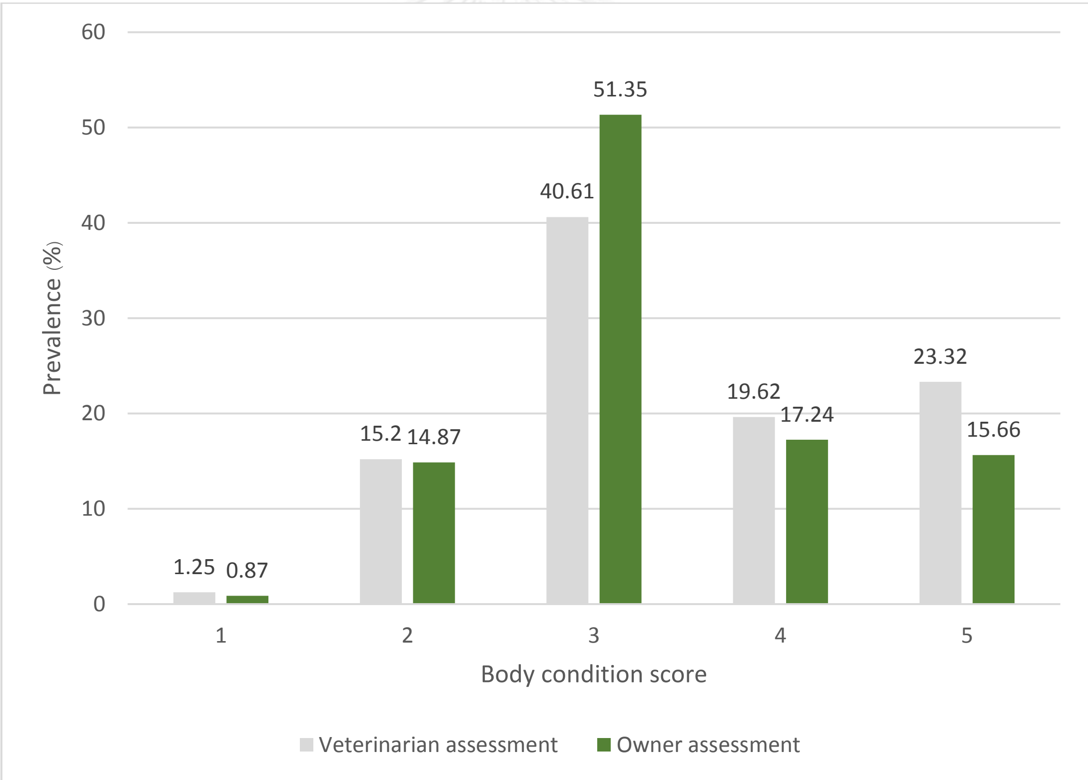


Figure 14 Comparison between proportion of dogs in each category of veterinarian assessment (Body Condition Score) and owner assessment (Body Conformation)

Owner misperception

The veterinarian assessments were compared with owner assessments (Table 13). Most owners (76.7%, n=1841) were able to evaluate their dog body shape correctly (gray area), however, some dogs owners underestimated (yellow area) (18.5%, n=443), and overestimated (white area) (4.9%, n= 117) their dogs. The highest underestimation was found in dogs with body condition score 4. The marginal homogeneity test by Stuart-Maxwell test can conclude that assessments of dogs by owners and veterinarian differs significantly ($p<0.0001$). The results of univariate logistic regression showed that age > 8 years old (OR=1.90) and neutering (OR =1.26) correlated with owner underestimation (Table 14).

Table 13 Comparison between veterinarian assessments and owner assessments.

		Owner assessment (Number of dogs)					
		1	2	3	4	5	Total
Veterinarian assessment (Number of dogs)	1	19	10	1	0	0	30
	2	0	309	56	0	0	365
	3	2	33	909	31	0	975
	4	0	5	200	247	19	471
	5	0	0	67	136	357	560
	Total	21	357	1,233	414	376	2,401

Table 14 Univariate logistic regression analysis between risk factors and owner underestimation

Risk factors	β	95% CI for EXP (β)	p-value	OR
Age				
3-8 years	0.52 (0.14)	1.28-2.19	<0.0001	1.70
>8 years	0.64 (0.16)	1.40-2.58	<0.0001	1.90
Neuter status				
Neutered	0.30 (0.11)	1.00-1.58	0.05	1.26

Part III Determination of the relationship between canine obesity and laboratory parameters

The 50 clinical healthy non-obese and 50 obese dogs with normal hematology were included in this study. The mean of each blood chemistry (ALT, ALP, total protein, albumin, cholesterol, and triglyceride) and thyroid level (Total T_4) were shown in Table 16. Cholesterol and triglyceride differed significantly between non-obese dogs and obese dogs. However, these parameters were within normal ranges,

Table 15 Comparison between blood parameters of non-obese dogs and obese dogs

Blood parameters	Dog weight categories (mean±S.D.)		p-value
	Non-obese dogs	Obese dogs	
ALT (U/L)	58.9±91.3	57.8±52.6	0.196
ALP (U/L)	78.2±73.3	102.1±218.6	0.357
Total protein (g/dL)	7.1±1.4	7.1±0.9	0.903
Albumin (g/dL)	3.0±0.5	3.1±0.4	0.098
Cholesterol (mg/dL)	178.8±62.5	226.8±83.0	0.001*
Triglyceride (mg/dL)	83.2±61.5	137.5±127.3	0.006*
Total T_4 (µg/dL)	1.7±0.7	1.8±0.6	0.387

Chapter V
Discussion

Part I Study of Prevalence and risk factors of canine obesity in Thailand

To our knowledge, this is the first study of canine obesity in Thailand in the national scale surveys. In this study, the prevalence of obesity was 42.94% which is consistent with previous surveys in Asia-China and Japan (Mao et al., 2013; Usui et al., 2016). However, it was higher than study in other continents, such as, US (Lund et al., 2006; Weeth et al., 2007) or Australia (Robertson, 2003; McGreevy et al., 2005).

Etiology of obesity is complex and contributed from both dog factors and owner factors. According to dog factors, age was considered to highly impact on obesity. In our study, the highest risk for obesity was found in middle-aged dogs and then, declined in dog aged over 10 years old. This results was similar with previous study (Lund et al., 2006). Hypotheses for these declined risk for dogs over 10 years of age may be associated with having aging-associated diseases (McGreevy et al., 2005) or maldigestion and malabsorption (Laflamme, 2012), thus losing their weight. So, the prevalence and the risk of obesity in old dogs were decreasing (McGreevy et al., 2005). Other dog factors was gender. There have been many reports showed that female dogs are more likely to be obese (McGreevy et al., 2005; Colliard et al., 2006; Mao et al., 2013). However, our study cannot show this association. A similar finding was observed in Australia (Robertson, 2003). In addition, neutering is a significant risk factors for canine. Results in this study is strongly consistent with previous studies (Robertson, 2003; McGreevy et al., 2005; Colliard et al., 2006; Lund et al., 2006; Mao et al., 2013; Usui et al., 2016). Gonadectomy removed the main sources of sex steroids-estrogen and androgen, which serves as satiety feedback to end food intake at hypothalamus. Recent study presented that castrated male cats had larger meal size than intact male cats, but the effect in dogs was still unknown (Backus and Wara, 2016).

Regarding breed of dogs and obesity, some specific breeds, such as Labrador Retriever, Australian Shepherd, Chihuahua, (Weeth et al., 2007), reported to be more prone to obesity. In our study, Beagles, Pug, Labrador Retriever and Golden Retriever were breeds which had high risk for obesity, which is similar to report in Japan and US (Lund et al., 2006; Usui et al., 2016). In Thailand, mixed-breed dogs are one of the most favored breeds. The present study showed that mixed breed dogs were also at risk for obesity similar to previous study (McGreevy et al., 2005).

Diet served as an influencing factor on canine obesity. In Thailand, owners tend to feed dogs with combination of commercial foods and non-commercial foods. This findings differed from previous studies, such as, China owners always fed non-commercial foods (Mao et al., 2013) or owners in France often fed their dogs with commercial foods (Colliard et al., 2006). In univariate analysis, there was risk for obesity in dogs fed with non-commercial food or combined food. However, after controlling other factors in multivariable analysis, food type was not associated with canine obesity. This may reflect that food type may not be a main factor of canine obesity in our study. Regarding of frequency of feeding, two previous reports has been noted (Courcier et al., 2010; Mao et al., 2013). As for feeding frequency, most of the owners in this study fed their dogs twice daily while a study in China showed that feeding several meals per days correlate with high dog obesity rate (Mao et al., 2013). In this and other study (Robertson, 2003) showed inversely evidence that feeding the dogs frequently can serve as protective effect for obesity. The potential reason may due to decreasing of meal size of food consumption. Furthermore, another hypothesis is divided a meal into several meals can create dietary thermogenesis more often, thus promoting energy loss (Robertson, 2003). Anyway, further study needs to investigate this finding. Snacking has always been of concern for canine obesity even though it is not main meal. In owner opinion, it was a way to represent pet-owner bonding relationship. Results in this and previous report in Australia, dogs were given snacks or treats frequently, they were risk for obesity due to excess energy intake (Robertson, 2003).

Dogs' environment plays a major role in obese condition. Study in Australia showed dogs in rural and semi-rural areas are at greater risk for obesity compared with dogs in urban area. It is because of easily access of food sources and less physical exercise (McGreevy et al., 2005). In contrast, dogs in our study were indoor living. These dogs were more likely to be obese because dogs kept indoor have limited area for movement and also physical activity. Only small numbers of owner concern about walking their dogs as routine exercise. Furthermore, the owners considered that dogs had wide areas to walk or run in the house, walking is not necessary (White et al., 2011). This may result in inadequate energy expenditure, therefore, contributing to increase in obesity. Additionally, this report showed the consistence care of dogs in the same household. Therefore, living with other obese dogs in the same household may prone to obesity. However, there was no statistical association between canine obesity and living with other obese cats in this study.

This study also investigated the association between concurrent diseases and risk factors of obesity. Dogs with skin diseases had high proportion of obese dogs. This may contribute from corticosteroid therapy which can promote food intake. Our study suggested that dogs with more than one concurrent diseases were at the greatest risk than dogs with single concurrent disease and healthy dogs. One possible reason is overfeeding by owners with intention to assist recovery of the dogs. Although many reports revealed obesity as a contributing factor to other diseases, such as respiratory disease, osteoarthritis and cognitive dysfunction (Bach et al., 2007; Laflamme, 2012). Awareness of owners regarding obese condition is still considerably low.

Owner factors were reported to affect with dogs' condition. Average owner BMI equals to 22.53±3.9 which less than the result studied in US (Heuberger and Wakshlag, 2011). In this study, prevalence of obesity in owners equals to 35.2%. Similar results were reported previously with 35% in Thai adults during 1991 to 2009 (Aekplakorn et al., 2014). Previous report about pet-ownership in Midwestern United States noted that normal weight owners had fewer health problems and take more supplement, frequently initiate dog activity and feeding supplement to their dogs more than overweight/obese owners (Heuberger and Wakshlag, 2011). Furthermore, the relationship of walking dogs and prevalence of obese owners was clearly defined. If the owners walk their dog by themselves, obesity rate is low (17%) compared with owners who did not walk their dogs (28%) and non-dog owners (22%) (Coleman et al., 2008). In the present study, only 11% of owners who are overweight or obese owned overweight and obese dogs. This was inconsistent with US study which fifty-nine percent of owners who are overweight or obese belonging with overweight and obese dogs (Heuberger and Wakshlag, 2011).

The limitation of this study is lack of recorded real amount of food intake and another source of caloric intake, thus, inability to estimate nutritional intake of individual dogs. In addition, the questionnaire did not include the total number of dogs and cats in the same household. The concurrent diseases were informed by owner, not by veterinarian diagnosis. This could lead to low reliability of information. Acknowledging the existence of canine obesity and risk factors related with this condition in Thailand can be as basis for prevention of obese dogs in the future, therefore reducing risk for severe disorders and increasing the dog's life span.

Part II Investigation of owner's misperception

The prevalence of canine obesity assessed by owners equals to 32.90% in this present study which was lower than those assessed by veterinarian. The high discrepancy was found in overweight dogs (dogs with BCS 4) similar to previous report

(White et al., 2011). Old dogs are more likely to be underestimated the body shape by owners. This is consistent with other published literature in United Kingdom (Courcier et al., 2011). The result showed that neutering is a contributing factor for owner underestimation also. However, this study could not identify association between owner BMI and underestimation of dog's body shape.

Part III Determination of the relationship between canine obesity and laboratory parameters

Regarding dogs' laboratory parameters, both cholesterol and triglyceride were significantly different between non-obese dogs and obese dogs. Although, current study about lipid parameters in obese and non-obese Boerboel dogs did not differ significantly (Ajadi et al., 2016). Many attempts to determine whether using lipoprotein profiles in clinical practice is useful to assess dogs with borderline obese body shape (Mori et al., 2011). The results in our study were consistent with several previous reports (Jeusette et al., 2006; Yamka et al., 2006; Peña et al., 2008). Additionally, the experiment by Diez et al. (2004) showed that these two parameters is decreasing in weight losing dogs and not associated with diet type. This support the potential benefits of lipid profiles to confirm obese condition in borderline dogs' body shape (Mori et al., 2011).

However, this study was limited by lack of fasting at least 12 hours prior blood collection. Fat content may induce the increasing of lipoprotein lipid levels, known postprandial hyperlipidemia. Some publication suggested that dietary fat can affect on triglyceride levels but the effect on cholesterol concentration is controversial (Mori et al., 2011).

In conclusion, this study confirmed the existence of canine obesity in Thailand. Risk factors of canine obesity were suggested so that veterinarians may construct an appropriate weight monitoring/controlling program for individual dogs. Some laboratory parameters have been found to relate to obesity and may be used as a part of diagnostic tool to confirm or promote awareness of the owners. More importantly, misperception of owner on evaluation of body conformation may lead to lack of concern and being an obstacle for weight control regimen. Client education is needed in order to have successful control of canine obesity.

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APPENDIX

Appendix 1 The distribution of each predictor variables and body weight categories of the 2,401 dogs

Predictor variables	Weight categories (N(%))		Total (N(%))
	Non-obese dogs	Obese dogs	
Age			
1-2 years	530 (22.1)	214 (8.9)	744 (31.0)
3-8 years	545 (22.7)	532 (22.2)	1,077 (44.9)
>8 years	295 (12.3)	285 (11.8)	580 (24.1)
Breed			
Small breed	745 (31.0)	519 (21.7)	1,264 (52.7)
Medium breed	540 (22.5)	433 (18.0)	973 (40.5)
Large breed	85 (3.5)	79 (3.3)	164 (6.8)
Gender			
Male	690 (28.7)	494 (20.6)	1,184 (49.3)
Female	680 (28.3)	537 (22.4)	1,217 (50.7)
Neuter status			
Intact	1,049 (43.7)	607 (25.3)	1,656 (69.0)
Neutered	321 (13.4)	424 (17.6)	745 (31.0)
Food type			
Only commercial food	336 (14.0)	205 (8.5)	541 (22.5)
Only homemade diet	113 (4.7)	115 (4.8)	228 (9.5)
Combined food	921 (38.4)	711 (29.6)	1,632 (68.0)
Frequency of feeding			
Once daily	156 (6.5)	186 (7.7)	342 (14.2)
Twice per day	1,023 (42.6)	708 (29.5)	1,731 (72.1)
Three times per day	71 (3.0)	44 (1.8)	115 (4.8)
Always available	120 (5.0)	93 (3.9)	213 (8.9)

Predictor variables	Weight categories (N(%))		Total (N(%))
	Non-obese dogs	Obese dogs	
Feeding snack or treat			
Once daily	318 (13.2)	321 (13.4)	639 (26.6)
Twice to three times per week	211 (8.8)	149 (6.2)	360 (15.0)
Once weekly	142 (5.9)	130 (5.4)	272 (11.3)
Once monthly	97 (4.0)	78 (3.3)	175 (7.3)
Less than one time per month	602 (25.1)	353 (14.7)	955 (39.8)
Living			
Indoor	1,250 (52.1)	951 (39.6)	2,201 (91.7)
Outdoor	120 (5.0)	80 (3.3)	200 (8.3)
Dogs that are overweight or obese in house			
Yes	1,016 (42.3)	568 (23.7)	1,584 (66.0)
No	354 (14.7)	463 (19.3)	817 (34.0)
Cats that are overweight or obese in house			
Yes	1,339 (55.8)	1,009 (42.0)	2,348 (97.8)
No	31 (1.3)	22 (0.9)	53 (2.2)
Concurrent diseases			
Healthy	859 (35.8)	554 (23.1)	1,413 (58.9)
Single concurrent disease	414 (17.2)	358 (14.9)	772 (32.1)
More than 1 disease	97 (4.0)	119 (5.0)	216 (9.0)
Owner BMI			
Underweight	182 (7.6)	155 (6.5)	337 (14.1)
Normal	827 (34.4)	612 (25.5)	1,439 (59.9)
Overweight	301 (12.5)	229 (9.5)	530 (22.0)
Obesity	60 (2.5)	35 (1.5)	95 (4.0)

VITA

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