

The effects of submaximal exercise training on cardiovascular functions and physical capacity in dogs with myxomatous mitral valve disease

Saikaew Sutayatram^{1*} Chollada Buranakarl¹ Anusak Kijawornrat¹

Kumpanart Soontornvipart² Pakit Boonpala¹ Prapawadee Pirintr³

Abstract

Myxomatous mitral valve disease (MMVD), an important disease in senile small breed dogs, leads to deterioration of cardiovascular function and impairment of functional capacity resulting in poor quality of life. Submaximal treadmill running has been used as both cardiovascular training and testing worldwide in humans and recently in animals. The objectives of this study were to examine the effects of submaximal endurance training (ET) by treadmill running on safety, adverse events, cardiovascular adaptations, hematology, functional capacity, and the feasibility of submaximal treadmill running test and 6-minute walk test (6-MWT) in dogs with MMVD. Six adult beagle dogs with MMVD, stage B1 according to the American College of Veterinary Internal Medicine (ACVIM) guideline, were examined before the study, at weeks 4 and 8 of the ET. The cardiovascular functions assessed by echocardiography and electrocardiography, systolic blood pressure, hematology and blood chemistry profiles, and functional capacity were determined. All dogs completed all tests and ET sessions without clinical complication. ET resulted in significant improvement in physical capacity measured by submaximal treadmill running test and 6-MWT, while cardiac function parameters were not altered. Moreover, serum creatinine was significantly decreased. In conclusion, ET and submaximal exercise tests are clinically feasible. The ET can improve physical capacity in dogs with MMVD, stage B1. Therefore, supervised moderate ET and submaximal exercise tests should be incorporated in MMVD management.

Keywords: cardiovascular function, dog, exercise training, myxomatous mitral valve disease, physical capacity

¹Department of Veterinary Physiology, Faculty of Veterinary Science, Chulalongkorn University, Henri Dunant Road, Pathumwan, Bangkok 10330, Thailand

²Department of Veterinary Surgery, Faculty of Veterinary Science, Chulalongkorn University, Henri Dunant Road, Pathumwan, Bangkok 10330, Thailand

³Department of Veterinary Bioscience and Veterinary Public Health, Faculty of Veterinary Medicine, Chiang Mai University, Mae Hia, Muang, Chiang Mai 50100, Thailand

*Correspondence: saikaew64@hotmail.com

Introduction

Myxomatous mitral valve disease (MMVD) is a common cardiovascular disease (CVD) and a major cause of cardiac mortality in adult dogs (Egenval et al., 2006). During disease progression, MMVD leads to several clinical challenges, in both electrical and mechanical deteriorations, from asymptomatic stage to severe congestive heart failure (CHF) and death.

In human CVDs management, besides specific interventions and medications, risk factor reduction programs are also comparably important. The most important CVDs risk factor is sedentary lifestyle, since it can augment other risk factors such as obesity, diabetic mellitus, high cholesterol, and high blood pressure. In pets, sedentary lifestyle can be a result of owners' inactive lifestyle or pets' limitations including systemic disease, physical disability, and geriatric age. The low physical activity in dogs is obvious in the metropolitan areas, especially in Asian countries, where regular dog walking and other dog physical activities are disregarded by one-third of the owners (Oka and Shibata, 2012) and environmental factors including hot and humid weather as well as public space are not suitable for dog outdoor activity. To improve this CVDs risk factor, regular aerobic exercise and endurance training (ET) have been incorporated to the CVDs management and showed several benefits on quality of life and cardiovascular functions in humans (Adachi et al., 1996) and dogs (Bonilla et al., 2012). In veterinary practice, ET with treadmill running in dogs with acquired MMVD significantly increased quality of life and physical activity measured by the Functional Evaluation of Cardiac Health (FETCH) score and treadmill running ability, but not by mechanical cardiovascular functions from echocardiographic variables (Marcondes-Santos et al., 2015). However, effects of ET on cardiovascular adaptations greatly depend on exercise intensity and duration of ET, as well as pre-existing cardiovascular adaptations and cardiovascular medications.

Treadmill running, both maximal and submaximal exercise testing protocols, also has been used as cardiovascular fitness test in humans (Pimentel et al., 2017) and in veterinary fields (Kittleson et al., 1996; Ferasin and Marcora, 2007; Marcondes-Santos et al., 2015). In addition, 6-minute walk test (6-MWT), a suitable test for daily functional capacity in patients with CDVs (Opasich et al., 2001), has been investigated its clinical potential in dogs with heart diseases (Boddy et al., 2004; Agudelo and Schanilec, 2013). However, usages of ET and functional test in general veterinary practice for dogs with heart disease are very limited, and the information on feasibility and adverse incidents associated with ET in dogs are insufficient. Most importantly, using forced exercise as treadmill running in untrained dogs, may result in stress or unwillingness (Kittleson et al., 1996) leading to adverse incidents or superimposed effects of ET when used in clinical setting. Thus, there are several challenges in creating ET guideline and functional testing for dogs with CVDs, especially in term of safety concerns.

The objectives of this study were, therefore, to evaluate safety, limitations, adverse incidents, cardiovascular adaptations, hematologic alterations,

and functional capacity, associated with treadmill submaximal ET, as well as the feasibility of using submaximal treadmill running test and 6-MWT in dogs with naturally acquired MMVD stage B1 classified by the American College of Veterinary Internal Medicine (ACVIM) staging system.

Materials and Methods

This study was approved by the Institutional Laboratory Animal Care and Use Committee of the Faculty of Veterinary Science, Chulalongkorn University (protocol No. 1531071). A total of 6 laboratory beagle dogs of mixed genders, age 8-13 years old, with MMVD, stage B1, were included in this study. Besides echocardiography, chest radiography was performed at the enrolment to evaluate vertebral heart score (VHS) and to exclude pulmonary disease. MMVD stage B1 was diagnosed as follows: a typical color jet across the mitral valve into the left atrial (LA) from color Doppler echocardiogram, and a valvular lesion of mitral valve from 2-D echocardiogram without cardiomegaly, defined as VHS less than 10.5, left atrial to aortic ratio (LA/Ao) less than 1.6, and normalized left ventricular internal diameter in diastole (LVIDDN), according to the Cornell formula (Cornell et al., 2004), less than 1.7 (Boswood et al., 2016).

The dogs were examined for the baseline time point including physical examination, blood pressure measurement, hematology and blood chemistry profile, echocardiography, electrocardiography (ECG), 1.5 hr of Holter monitoring, submaximal treadmill running test, and 6-MWT. The qualitative parameter such as mental status, neurological reflex, exercise performance and physical injury were also recorded. Then, all dogs were subjected to treadmill submaximal ET for 8 weeks. All parameters and tests were re-evaluated at weeks 4 and 8 of the ET program.

Hematology and blood chemistry parameter: Blood profiles were analyzed using automate machines (Mindray BC-5000VET, Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China and IL LAB 650 Chemistry Analyzer, Diamond diagnostics, MA, USA) for complete blood count and serum chemistry profiles (i.e., glutamic pyruvic transaminase (SGPT), alkaline phosphatase (ALP), total protein, albumin, blood urea nitrogen (BUN), and creatinine).

Cardiac function parameter: Echocardiography was performed consciously using an echocardiographic system (Medison EK07, Samsung Medison Co., Ltd., Korea) by a trained veterinarian, blinded with the dogs' exercise performance. The Echocardiographic parameters were obtained according to previous study (Boswood et al., 2016). The calculated functional parameters such as end diastolic volume (EDV), end systolic volume (ESV), and ejection fraction (EF) were formulated using Teichholz formula (Teichholz et al., 1976). The Doppler echocardiogram was also performed to evaluate transmitral inflow including LV early (E) to late (A) ventricular filling velocities from the left apical 4-chamber view and myocardial

performance index or LV Tei index from the left apical 5-chamber view.

Systolic blood pressure (SBP) was measured at the left front leg during right lateral recumbency using an oscillometric device (PetMAP™ graphic system, Ramsey Medical, Inc., FA, USA) according to a previous validation method (Vachon et al., 2014), at before, immediately and 30 minutes after each submaximal treadmill running test.

Electrocardiogram (ECG): ECG was recorded 30 minutes before starting each submaximal treadmill running test using an electrocardiograph (CardiMax FX-7102, Fukuda Denshi Co., Ltd., Japan). A Holter device (Digital Walk FM-180, Fukuda Denshi Co., Ltd., Japan) was attached to the dogs, and HR and arrhythmia were recorded at before, during, and after submaximal treadmill running test. The data were stored in an SD card and were analyzed using a specific software (HCM 500) followed by a manually editing process.

Submaximal treadmill running test: Submaximal treadmill running test was performed using a treadmill (DK City DK-4718W, DK City Co., Taiwan). The test was adapted from a dog effort test protocol (Marcondes-Santos et al., 2015) as followed: treadmill speed was turned on at 0.8 - 2 km/hr for 5 min (warm-up), then speed was increased by 1 km/hr for each 2 min, and the stepwise increase was repeated until dogs show signs of exhaustion. At this point the speed was immediately reduced to the rate, at which the dog was able to run without exhaustion until the 16th minute. Finally, the speed was gradually slowed down to 0.8 - 2 km/hr during the last 4 min for cooling down. In case of serious exhaustion or adverse incidents, the test was terminated. The submaximal treadmill running test parameters, i.e., maximum treadmill speed (Vmax), total time until first sign of exhaustion (Texh), total running time (Ttotal), and highest heart rate (HHR), as well as adverse incidents were recorded for each test session.

Six-minute walk test: Dogs were trained to walk with chest harness attached to a short leash three days before 6-MWT. All 6-MWT was performed with a veterinarian in the quiet and safe air-conditioned room. The floor distances were marked for each meter creating a rectangle walk path, 6 m x 8 m in size, and dogs were guided to walk on it. After acclimatization to the room, the 6-MWT was started when the dog started to walk on the path and the walk was stopped at the 6th minute, then total walk distance was calculated from total walk laps and additional meters.

Submaximal endurance training protocol: The submaximal ET session was performed in the same setting of the submaximal treadmill running test. In brief, the 20-min ET session started with 5 min of warm-up, then treadmill speed was gradually increased within 3 min to the speed that cause exhaustion from the previous submaximal treadmill running test or last ET session, and the speed was adjusted to the dog performances, followed by the last

4 minute cool-down period. The ET session was performed twice per week for a total of 8 weeks.

Statistics: All parameters from 6 dogs were grouped as time point (i.e., before, and after weeks 4 and 8 of ET) and presented as mean and standard error of the mean (SEM). All parametric data were compared among time points with one-way ANOVA repeated measurement, followed by Dunnett's multiple comparison post hoc test. *P*-value less than 0.05 was considered statistically significant difference.

Results

All 6 dogs completed all of submaximal exercise tests and 8-week ET program. None of the exercise-induced adverse incident, either hemodynamic disturbance or injury, was found.

Hematology and blood chemistry parameter: Blood profiles revealed that the dogs mostly had the values within normal limit throughout the study, except slight elevation of ALP in two dogs, ranging from 101 to 190 U/L. At week 8 of the ET program, there was a significant reduction in red blood cell counts (10^6 cell/ μ L) (6.68 ± 0.54 vs 5.92 ± 0.35 for baseline and after 8-week ET program, respectively, $P < 0.05$) and creatinine levels (mg/dL) (0.73 ± 0.06 vs 0.52 ± 0.04 , for baseline and after 8-week ET program, respectively, $P < 0.05$).

Cardiac function measurement: The conscious echocardiographic data were presented in Table 1. The 8-week of ET did not statistically alter cardiac structural and functional parameters. Also, the ET program could neither significantly alter the resting SBP (mmHg) (164 ± 3 , 166 ± 6 and 159 ± 6 for baseline, weeks 4 and 8 of training, respectively) nor induce hemodynamic adverse incident.

Electrocardiography: There was no significant difference among time points for resting HR (bpm) (106 ± 6 , 112 ± 4 , and 116 ± 4 for baseline, weeks 4 and 8 of training) and lead II ECG parameters in both amplitude and duration.

The ectopic beats and arrhythmia were presented in Table 2, and the time points were defined as before (Before run), during (Run), and after (Recovery) submaximal treadmill running test. The ectopic beats were detected in four out of six dogs (dog no. 2, 3, 5 and 6). These ectopic beats were single ventricular premature complex (VPC) originated from either the left or the right ventricle, and supraventricular premature complex (SVPC) including atrial and junctional premature complexes. The second degree atrioventricular block (AVB) was only observed in one dog (dog no. 5) during recovery period of the baseline time point.

Submaximal treadmill running test: The results of all submaximal treadmill running test parameters in each time point were presented in Table 3. The Vmax were significantly higher at both weeks 4 and 8 of ET program than that of the baseline ($P < 0.001$ and $P < 0.05$, respectively). Whereas, Texh and Ttotal

significantly improved only at week 8 of ET program compared with the baseline values ($P < 0.05$). However, HHR showed no statistical difference among time points. The common signs of exhaustion during this test were pale mucous membrane color, increased respiratory rate with dyspnea, and hind limb muscular weakness, but all of these signs could be reversed within a few minutes after speed reduction or test termination.

Six-minute walk test: The 6-MWT in this study revealed that this ET program significantly improved functional capacity in these dogs, as the distances at both weeks 4 and 8 of training program were longer than that of the baseline value (m) (278.8 ± 22.7 , 368.0 ± 32.0 , and 456.8 ± 35.5 for baseline, week 4 and 8 of training, respectively, $P < 0.001$).

Table 1 Echocardiographic parameters obtained from conscious dogs at baseline, week 4, and week 8 after starting the ET program

Echocardiographic parameters	Baseline	Week 4	Week 8
LA/Ao	1.22 ± 0.15	1.17 ± 0.13	1.19 ± 0.16
IVSd (cm)	0.99 ± 0.11	0.98 ± 0.07	0.99 ± 0.09
IVSs (cm)	1.29 ± 0.05	1.25 ± 0.07	1.22 ± 0.13
LVIDd (cm)	3.03 ± 0.21	2.93 ± 0.24	3.19 ± 0.29
LVIDDN	1.34 ± 0.08	1.30 ± 0.09	1.43 ± 0.13
LVIDs (cm)	1.94 ± 0.22	1.97 ± 0.20	2.17 ± 0.22
LVPWd (cm)	0.95 ± 0.09	0.96 ± 0.10	0.85 ± 0.08
LVPWs (cm)	1.18 ± 0.09	1.13 ± 0.10	1.08 ± 0.09
FS (%)	36.5 ± 4.3	32.6 ± 4.3	31.3 ± 5.8
HR (beats per minute)	117 ± 6	116 ± 6	121 ± 9
LVEDV (mL)	37.22 ± 5.78	34.70 ± 5.92	43.37 ± 9.28
LVESV (mL)	13.21 ± 3.52	13.39 ± 2.99	17.11 ± 4.26
SV (mL)	24.01 ± 3.67	21.31 ± 4.10	26.26 ± 6.07
CO (L)	2.87 ± 0.52	2.53 ± 0.54	3.25 ± 0.90
EF (%)	66.5 ± 5.7	61.3 ± 5.1	57.9 ± 8.0
E/A	1.14 ± 0.20	1.22 ± 0.16	1.15 ± 0.15
LV Tei Index	0.73 ± 0.03	0.69 ± 0.06	0.72 ± 0.06

LA/Ao = Left atrium/Aorta ratio; IVSd = interventricular septum diastole; IVSs = interventricular septum systole; LVIDd = left ventricular internal dimension diastole; LVIDDN = normalized left ventricular internal diameter in diastole; LVIDs = left ventricular internal dimension systole; LVPWd = left ventricular posterior wall diastole; LVPWs = left ventricular posterior wall systole; FS = fractional shortening; HR = heart rate; LVEDV = left ventricular end-diastolic volume; LVESV = left ventricular end-systolic volume; SV = stroke volume; CO = cardiac output; EF = ejection fraction; E/A = Left ventricular early (E) to late (A) ventricular filling velocities ratio.

Table 2 Arrhythmias count from ambulatory ECGs during each submaximal treadmill running test

Arrhythmias	Baseline	Week 4	Week 8
	Animal number (beats; n)	Animal number (beats; n)	Animal number (beats; n)
Before run (30 min)			
VPC	3(4)	2(1), 3(2), 5(1)	3(1), 6(2)
SVPC	2(1), 3(9)	-	3(1)
AVB	-	-	-
Run (20 min)			
VPC	3(2)	-	-
SVPC	3(11), 5(1)	-	3(18)
AVB	-	-	-
Recovery (30 min)			
VPC	3(5)	-	6(1)
SVPC	3(3)	3(5)	3(2)
AVB	5(1)	-	-

VPC, ventricular premature complex; SVPC, supraventricular premature complex; AVB, atrioventricular block.

Table 3 Submaximal treadmill running test parameters in each time point

Submaximal treadmill running test parameters	Baseline	Week 4	Week 8
Vmax (km/hr.)	3.07 ± 0.43	3.68 ± 0.34^a	4.65 ± 0.43^b
Texh (min)	10.92 ± 1.17	13.25 ± 1.20	14.47 ± 0.58^b
Ttotal (min)	17.17 ± 1.04	19.43 ± 0.57	20.00 ± 0.00^b
HHR (bpm)	177 ± 10	185 ± 12	194 ± 8

Vmax, maximum treadmill speed; Texh, total time until first sign of exhaustion; Ttotal, total running time; HHR, highest heart rate.

a, significant differences between baseline and week 4 of ET time point with $P < 0.001$.

b, significant differences between baseline and week 8 of ET time point with $P < 0.05$.

Discussion

This is the first study to our knowledge that can prove that the 8-week submaximal ET with a

treadmill and both submaximal exercise tests are feasible in MMVD, stage B1 dogs in terms of compliance and safety. The ET also significantly improved physical capacity. However, this ET could

not produce clinical alteration in cardiovascular parameters either electrical or mechanical variables as well as other physical examination parameters.

For feasibility, the compliant rate measured from the total success training or testing sessions was high in this study. Although the dogs were reluctant to step on the treadmill at first, playful gestures and vocal encouragement during walking the dog onto the treadmill together with the trainer were finally able to persuade the dogs to run on the treadmill. With the progression of the ET program, dogs showed higher compliance and enjoyed the training as observed by behavioral changes and less required human restrain on the treadmill. Moreover, both treadmill running regimens as the ET and the submaximal treadmill running test were safe and tolerable for these untrained dogs. None of the dogs exhibited serious adverse incident during treadmill running in the hemodynamic or clinical points. These findings were compatible with the results of the ET program in dogs with various degrees of acquired chronic mitral valve disease using supervised ET together with conventional treatments (Marcondes-Santos et al., 2015). In dogs with stable mitral regurgitation (MR), there was no difference between the incidence of cardiovascular adverse events and survival rate between conventional treatment with ET and without ET groups. Likewise, in dogs with acquired heart failure, submaximal treadmill running test with comparable speed to our protocol did not create clinical adverse incident or significant elevation of plasma troponin-I, even in dogs with atrial fibrillation (Ferasin and Marcora, 2007). A previous study showed that the 18-min treadmill running with the highest speed of 6.4 km/hr at 16% graded or β -adrenergic agonist administration progressively increased HR, but reduced myocardial electrical impedance (MEI) in dogs with healed myocardial infarctions, indicating that increased stimulation of β -adrenergic receptors during exercise could augment a risk of arrhythmia (Del Rio et al., 2015). However, in our study, the ectopic beats (monomorphic VPCs and SVPCs) and second degree AVB were transient, and did not produce clinical signs nor clinical relevance to physical performance, stage of exercise, or training progression. Therefore, these abnormal electrical events could be mixed results of natural maladaptations induced by MR, individual variation, extracardiac cause, and sympathetic activation provoked by excitement and exercise.

Another general ET consideration is worsening of clinical outcomes. However, the blood profiles in these dogs indicated statistically significant decrease in serum creatinine level at the end of ET program, concordantly with the effect of treadmill training in sedentary healthy dogs (Vrbanac et al., 2016). This serum creatinine reduction seemed to be irrelevant with lean body mass in this study since the body weights remained constant while there was a decline in the body mass of those sedentary healthy dogs. Although, serum creatinine is not a sensitive renal function indicator. Many hemodynamic and systemic factors associated with ET that might play a major role in renal filtration improvement, such as enhancement in glomerular filtration rate (Heifets et al., 1987), arterial stiffness (Mustata et al., 2011), and

endothelium-dependent vasodilation capacity (DeSouza et al., 2000), as well as, increase in plasma volume (Convertino et al., 1983) were reported. Thus, renal filtration improvement induced by ET might also occur in this study. Nevertheless, the lack of serious adverse incident and high compliance rate in this study might correlate with mild disease status in these dogs, nature of submaximal test and training, well controlled setting, cooperative of the animals, and experience of the trainers. Therefore, applying these tests and ET program in the clinical situation might require further investigation and adjustments for each case, especially in different program settings or groups of dogs.

In terms of cardiovascular function, this ET program could not clinically alter mechanical cardiovascular parameters. Although physical training improved echocardiographic parameters in several studies such as healthy rats (Kemi et al., 2004), and experimentally induced myocardial ischemia (MI) dogs (Billman, and Kukielka, 2006). The non-remarkable change of echocardiographic findings in this study was similar with a previous exercise training in dogs with naturally acquired chronic mitral valve disease (Marcondes-Santos et al., 2015). Likewise, the lack of significant cardiovascular improvement also exhibited in ECG in this study corresponding with a study in submaximal exercise training in walking and stationary cycling in senile MI patients (Duru et al., 2000). These smaller effects of exercise training in cardiac functions in our study could be associated with the differences in disease status, intensity and duration of exercise training, and characteristic of study subject. Dogs in this study had smaller maladaptations of cardiovascular functions, as most of the cardiovascular parameters were within normal limits. Also, dogs with naturally acquired mitral valve disease are usually older and have concomitant degenerative problems that may attenuate physical ability to perform high intensity treadmill exercise, while those experimental MI dogs were approximately 1-4 year old without other underlying health problems. Moreover, in this study, both intensity (speed and incline of treadmill) and duration (i.e., total time per each session, number of session per week, and total weeks of training) of exercise training that highly impact the exercise benefits were noticeably lower than those of the MI dogs, owing to our dogs' limitation in physical capacity, safety precaution, and the suitability in clinical practice. Nevertheless, a longer ET program study in these MMVD dogs that evaluates both cardiovascular function and duration of asymptomatic phase may be helpful to elucidate the longer accumulative effects of ET on cardiovascular status and clinical outcomes.

For physical capacity, both submaximal treadmill running test and 6-MWT are well known for their reliability to measure physical capacity in humans for both healthy and cardiovascular disease settings (Opasich et al., 2001; Rostagno et al., 2003). Recently, these tests have been applied in veterinary field, especially in dogs. In this study, both tests were able to quantitatively measure physical capacity improvement associated with the ET. With the progression of the ET program, submaximal treadmill running test parameters for both intensity and

duration, as well as distance of 6-MWT, gradually increased, indicating that the aerobic capacity was augmented. These findings correlated with other studies in dogs. For instance, the study in acquired chronic MR dogs showed that mean speed rate during treadmill running concomitantly increased with improvements of physical conditioning, functional class, and quality of life measured by the FETCH score (Marcondes-Santos et al., 2015). Likewise, another study in acquired heart failure dogs revealed that total running time before exhaustion was longer after prescribing cardiac medication, and the submaximal exercise test could reflect cardiac response to the treatment (Ferasin and Marcora, 2007). For 6-MWT, the walk distance was also significantly shorter in dogs with mild to moderate degenerative mitral valve disease (Agudelo and Schanilec, 2013), and dogs with pacing induced congestive heart failure (Boddy et al., 2004), compared with those of healthy dogs. Additionally, the improved physical capacity was consistent with better quality of life in terms of dogs' behavior, alertness, physical activities, and skeletal muscle tone observed in our study. However, the 6-MWT level at the baseline in this study was lower than other studies. This could be a result of the difference in test setting, as well as dogs' anatomical and pathophysiological status. Alike, Vmax could be affected by underlying concomitant disease of the dogs and dog breed that determine gait ergonomics. Furthermore, dogs' routine exercise, beside the ET program, in this study were low in both levels of duration (i.e., approximately 60 min/week) and intensity (i.e., short-walking and supervised group-playing), therefore their physical capacity might be as low as those of sedentary dogs.

In terms of application, both physical capacity tests may provide better evaluation in physical capacity alterations induced by diseases and clinical treatments, especially in the cases that the owners cannot provide history of their dogs, or perform physical activity with their dogs. However, in this study, submaximal treadmill running test may have a lower ability to predict physical capacity in normal daily activity, compared with 6-MWT. One overweight dog in this study exhibited marked improvement in the distance of 6-MWT with a reduction of body condition score, while the Vmax was not noticeably increased at the similar degree. Thus, 6-MWT showed higher feasibility and reliability in overweight dogs or dogs with other conditions that interfere high intensity exercise, in other words, 6-MWT is a more appropriate physical capacity test for normal or low to moderate intensity physical activities. On the other hand, increased physical capacity induced by ET in this study could not be implied from resting cardiovascular parameters. This finding is also supported by the study in heart failure patients in which the resting LV structure and function were not associated with exercise capacity (Mohammed et al., 2014). Moreover, in elderly heart failure patients with preserved ejection fraction, exercise intolerance was depended on arterial-venous oxygen content difference, but not LV volumes from echocardiography, indicating that non-cardiac factors were major determinants of physical capacity in this group of patients (Haykowsky et al., 2011). The

improvement of physical capacity in our study might result from exercise training induced adaptations in coronary vascular structure and function, musculoskeletal status (Yalamanchi et al., 2016), metabolism (Uribe et al., 2016), and neurohormonal function (Gielen et al., 2010), as reported in several previous studies. Moreover, dogs in this study were more sedentary compared with pet dogs with active lifestyle, therefore, some physical degenerations might already exist leading to obvious physical capacity improvement.

In conclusion, supervised or moderate regular exercise that is within the individual physical capacity should be performed in subclinical MMVD dogs and dogs with low routine physical activity, in order to preserve or improve physical capacity and quality of life. Also, submaximal treadmill running test and 6-MWT can be incorporated in MR management. More caution should be placed in the animals with severe cardiovascular disease and with other health problems that contradict to intense exercise.

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บทคัดย่อ

ผลของการฝึกออกกำลังกายต่อการทำงานของหัวใจและหลอดเลือด และสมรรถภาพทางกายในสุนัขที่มีภาวะลิ้นไมทรัลเสื่อม

ทรายแก้ว สัตยธรรม^{1*} ชลดา บุรณกาล¹ อนุศักดิ์ กิจถาวรรัตน์¹
กัมปนาท สุนทรวิภาต² ปกิตต์ บุญพละ¹ ประภาวดี ไพรินทร์³

ภาวะลิ้นไมทรัลเสื่อมแบบ myxomatous degeneration (myxomatous mitral valve disease; MMVD) เป็นภาวะที่สำคัญและพบได้มากในสุนัขขนาดเล็กสูงอายุ ซึ่งนำไปสู่การลดประสิทธิภาพการทำงานของหัวใจและหลอดเลือด รวมทั้งสมรรถภาพทางกาย ทำให้มีคุณภาพชีวิตลดลง ในปัจจุบันการออกกำลังกายโดยการวิ่งบนลู่วิ่งไฟฟ้าที่ใช้ทั้งเพื่อการฟื้นฟู และเพื่อประเมินสมรรถภาพของผู้ป่วยเริ่มมีการนำมาประยุกต์ใช้ในสัตว์ป่วย งานวิจัยนี้จึงมีวัตถุประสงค์เพื่อศึกษาผลของการฝึกออกกำลังกายด้วยลู่วิ่งไฟฟ้าแบบ submaximal endurance training (ET) ทั้งในด้านของความปลอดภัย ผลอันไม่พึงประสงค์ การเปลี่ยนแปลงการทำงานของหัวใจและหลอดเลือด ค่าโลหิตวิทยา และสมรรถภาพทางกาย รวมถึงความเหมาะสมของการนำการวิ่งบนลู่วิ่งไฟฟ้าแบบ submaximal treadmill running test และการเดินแบบ 6-minute walk test (6-MWT) มาใช้เป็นวิธีการตรวจประเมินสมรรถภาพทางกายในสุนัขที่มีภาวะ MMVD โดยนำสุนัขพันธุ์บีเกิ้ลหกตัวที่มีภาวะ MMVD ในระยะ B1 ตามวิธีการจำแนกของ the American College of Veterinary Internal Medicine (ACVIM) มาทำการศึกษาก่อนเริ่ม และที่สี่และแปดสัปดาห์ของการฝึก ET โดยการประเมินการทำงานของหัวใจและหลอดเลือดด้วยการบันทึกภาพหัวใจด้วยคลื่นเสียงความถี่สูง และคลื่นไฟฟ้าหัวใจ การวัดความดันโลหิต การตรวจค่าโลหิตวิทยา และการประเมินสมรรถภาพทางกาย จากการศึกษาพบว่าสุนัขทุกตัวผ่านการทดสอบและการฝึก ET โดยไม่ก่อให้เกิดผลที่ไม่พึงประสงค์ และการฝึก ET สามารถพัฒนาสมรรถภาพทางกายได้อย่างมีนัยสำคัญทางสถิติจากการตรวจประเมินสมรรถภาพทางกายทั้ง submaximal treadmill running test และ 6-MWT โดยไม่พบการเปลี่ยนแปลงการทำงานของหัวใจและหลอดเลือด นอกจากนี้การฝึก ET ยังสามารถลดค่า creatinine ในซีรัมได้อย่างมีนัยสำคัญทางสถิติ จากการศึกษาครั้งนี้สามารถสรุปได้ว่าการฝึก ET และการตรวจประเมินสมรรถภาพทางกายทั้งสองวิธีมีความเหมาะสมต่อการนำมาใช้ในทางคลินิก และการฝึก ET สามารถพัฒนาสมรรถภาพทางกายของสุนัขที่มีภาวะ MMVD ดังนั้นการฝึกออกกำลังกายภายใต้การควบคุมดูแลและการตรวจประเมินสมรรถภาพทางกายควรถูกนำมาใช้ในการจัดการภาวะ MMVD ในสุนัข

คำสำคัญ: การทำงานของหัวใจและหลอดเลือด สุนัข การฝึกออกกำลังกาย ภาวะลิ้นไมทรัลเสื่อม สมรรถภาพทางกาย

¹ภาควิชาสัตววิทยา ²ภาควิชาสัตวศาสตร์ คณะสัตวแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ปทุมวัน กรุงเทพฯ ฯ 10330

³ภาควิชาชีวศาสตร์ทางสัตวแพทย์และสัตวแพทย์สาธารณสุข คณะสัตวแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่ ตำบลแม่เหียะ อำเภอเมือง จังหวัดเชียงใหม่ 50100

*ผู้รับผิดชอบบทความ E-mail: saikaew64@hotmail.com