Original Article

Heart Rate Change during Aquatic Exercise in Small, Medium and Large Healthy Dogs

Korakot Nganvongpanit[1,2*] Siriphun Kongsawasdi[3] Bussaba Chuatrakoon[3] Terdsak Yano[4]

Abstract

This study was divided into two experiments. For the first experiment, heart rates during exercise of 21 healthy male dogs were recorded. The animals were brought to swim every 2 days, 8 times in all, for 10 minutes. Heart rates were measured every minute using a pulse watch. For the second experiment, 134 healthy adult dogs were categorized into three groups: small (41), medium (51) and large breed (42). Their heart rates were measured every minute for 34 minutes after the 5th swimming. In the first experiment, the heart rates during the 1st–4th swimming were significantly higher (p<0.05) than during the 5th 8th swimming. In the second experiment, the heart rates were significantly different (p<0.05) between small, medium and large dogs. No correlations were found between weight, age, and heart rate. From the results of the second experiment, we were able to formulate an equation for predictable heart rate of each group of dogs (small, medium and large dogs). From the results, we recommend that the limits on the length of time spent for aquatic exercise should be 15–30 minutes, depending on the breed (size) of dog. Moreover, there should be trainers observing each dog to prevent over-exercise.

Keywords: dog, heart rate, swimming

[1]*Bone and Joint Research Laboratory, Department of Veterinary Biosciences and Public Health, Faculty of Veterinary Medicine, Chiang Mai University, Chiang Mai 50100, Thailand*
[2]*Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[3]*Department of Physical Therapy, Faculty of Associated Medical Science, Chiang Mai University, Chiang Mai 50200, Thailand*
[4]*Department of Food Animals, Faculty of Veterinary Medicine, Chiang Mai University, Chiang Mai 50100, Thailand*
***Corresponding author: E-mail:** korakot.n@cmu.ac.th; korakot_n@hotmail.com*

บทคัดย่อ

การเปลี่ยนแปลงของอัตราการเต้นของหัวใจของ สุนัขขนาดเล็ก กลาง และใหญ่ที่สุขภาพดี ในขณะออกกำลังกายในน้ำ

กรกฎ งานวงศ์พาณิชย์ [1,2] ศิริพันธุ์ คงสวัสดิ์ [3] บุษบา ฉั่วตระกูล [3] เทิดศักดิ์ ยาโน [4]*

ทำการศึกษาการเปลี่ยนแปลงอัตราการเต้นของหัวใจของสุนัขที่สุขภาพดีในขณะว่ายน้ำ โดยแบ่งการศึกษาเป็น 2 การทดลอง การทดลองที่ 1 เก็บข้อมูลจาก สุนัขเพศผู้ที่สุขภาพดี จำนวน 21 ตัว ที่ให้ว่ายน้ำทุกๆ 2 วัน ติดต่อกัน 8 ครั้งๆ ละ 10 นาที และทำการวัดอัตราการเต้นของหัวใจขณะว่ายน้ำทุกนาที การทดลองที่ 2 เก็บข้อมูลจาก สุนัขสุขภาพดี จำนวน 134 ตัว ซึ่งแบ่งเป็น 3 กลุ่ม ได้แก่ สุนัขขนาดเล็ก (41 ตัว) ขนาดกลาง (51 ตัว) และขนาดใหญ่ (42 ตัว) ทำการวัดอัตราการเต้นของหัวใจทุกนาที ติดต่อกัน 34 นาที หลังการว่ายน้ำครั้งที่ 5 การทดลองที่ 1 พบว่า อัตราการเต้นของหัวใจของสุนัขขณะว่ายน้ำ ใน 4 ครั้งแรกสูงกว่าในครั้งที่ 5 ถึง 8 ($p<0.05$) การทดลองที่ 2 พบว่า อัตราการเต้นของหัวใจของสุนัขขนาดเล็ก กลาง และใหญ่ มีความแตกต่างกันทางสถิติ ($p<0.05$) และไม่พบความสัมพันธ์ระหว่างน้ำหนักร่างกาย และอายุกับอัตราการเต้นของหัวใจ นอกจากนี้ค่าอัตราการเต้นของหัวใจที่บันทึกได้จากการทดลอง สามารถนำมาสร้างเป็นสมการหาอัตราการเต้นของหัวใจของสุนัขแต่ละขนาด (เล็ก กลาง และใหญ่) ขณะว่ายน้ำ จากการศึกษา แนะนำให้สุนัขว่ายน้ำติดต่อกัน 15 ถึง 30 นาที ขึ้นอยู่กับขนาดของสุนัขและผู้ควบคุมการออกกำลังกายต้องคอยสังเกตอาการของสุนัขแต่ละตัวเพื่อป้องกันการออกกำลังกายมากเกินความสามารถ

คำสำคัญ: สุนัข อัตราการเต้นของหัวใจ ว่ายน้ำ

[1]ห้องปฏิบัติการวิจัยโรคกระดูกและข้อในสัตว์ ภาควิชาชีวศาสตร์ทางสัตวแพทย์และสัตวแพทย์สาธารณสุข คณะสัตวแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่ อ. เมือง จ. เชียงใหม่ 50100 ประเทศไทย

[2]ศูนย์วิจัยวัสดุศาสตร์ คณะวิทยาศาสตร์ มหาวิทยาลัยเชียงใหม่ อ. เมือง จ. เชียงใหม่ 50200 ประเทศไทย

[3]ภาควิชากายภาพบำบัด คณะเทคนิคการแพทย์ มหาวิทยาลัยเชียงใหม่ อ. เมือง จ. เชียงใหม่ 50200 ประเทศไทย

[4]ภาควิชาสัตว์บริโภค คณะสัตวแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่ อ. เมือง จ. เชียงใหม่ 50100 ประเทศไทย

***ผู้รับผิดชอบบทความ E-mail:** korakot.n@cmu.ac.th; korakot_n@hotmail.com*

Introduction

Aquatic exercise is an exercise that is performed in the water, for the purposes of strengthening muscles and increasing physical fitness. Aquatic exercise is often praised because it has a low impact on joints and bones, so it is frequently used for rehabilitation following an injury. Aquatic therapy can be beneficial by minimizing weight-bearing forces and allowing patient to improve range of joint motion and muscle strength (Oblby et al., 2005). There are many different ways to exercise in the water, and these can offer both aerobic and strength benefits, as well as weight loss.

One of the simplest types of aquatic exercise is swimming. Swimming is an aerobic exercise that also increases muscular strength throughout the entire body. In addition to swimming, water-walking and water-jogging are also popular aquatic exercises. Walking or jogging in water provides a gentle resistance without placing any impact on the joints. It is also possible to jog in deep water, without the feet even touching the bottom of the pool. As these exercises become easier, the speed or the length of time spent doing them can simply be increased in order to increase their difficulty.

The benefits of aquatic exercise arise from two main factors: buoyancy and resistance. Buoyancy provides support to weak muscles for reassured balance and improved posture by simply standing in the pool. Movement will become less guarded as the fear of falling is significantly reduced, leading to movement success. This success will translate into feelings of enjoyment and the desire to participate regularly. Buoyancy reduces the impact of stress on the joints, and often allows greater mobility. The buoyant force of water results in up to a 90% reduction in body weight in the water (Di Prampero, 1986). The resistance is provided by the water that surrounds exercising participant. This multi-directional resistance helps the individual to maintain or enhance muscular strength and endurance even with gentle movements. Water resistance also enhances body awareness, which can assist in maintaining proper posture and a sense of movement within a given space during a particular activity.

The circulatory system plays a central role in aerobic exercise by linking the sites of gas exchange in the body. It is necessary to understand the influence of aquatic exercise on cardiac hemodynamics in order to perform safe and effective aquatic physiotherapy. Heart rate change during aquatic exercise has not previously been measured in dogs. To clarify the change of heart rate during swimming, we therefore sought to measure the heart rate response in healthy dogs during swimming.

Materials and Methods

This study was divided into two experiments. The first experiment studied the relationship between swimming time and heart rate change. The second experiment studied the heart rate change in different dog breeds (sizes). The experimental protocol was approved by the Faculty of Veterinary Medicine and the Ethics Committee, Chiang Mai University, Thailand.

Experiment 1

Animals: Twenty-one healthy male dogs were used as the subjects of this experiment, with an average age of 32.57±8.23 months and an average weight of 16.64±1.92 kg. Prior to admission to the study, health status was examined by a veterinarian; this included recording the animal's medical history, a physical examination and a blood profile evaluation. Animals with cardiovascular, metabolic or infectious diseases were excluded from the study to avoid the risk of adverse events. Moreover, all animals had never gone swimming before participating in this experiment.

Measurements: An outdoor pool was used for aquatic exercise, with a water temperature between 30-35^{0}C. All animals were allowed to swim a total of 8 times in order to collect the data. Swimming times were measured over a 2 days period, 4 times each day. Each animal's heart rate was measured using a pulse watch (CHF-100-1VDR, Casio) every minute for 10 minutes.

Statistical analysis: The heart rates of all animals at each swimming time were used to calculate mean and standard deviation (SD). All data were analyzed using the Statistical Analysis System (SAS) version 8.0 (SAS Institute Inc, Cary NC, USA) software package. Differences in mean values between two or more experimental groups or developmental stages were tested using ANOVA followed by multiple pairwise comparisons using a t-test. Differences of $p<0.05$ were considered to be significant. Moreover, a Pearson's correlation (r) test between heart rate and swimming time in dogs was also calculated.

Experiment 2

Animals: One hundred thirty-four healthy adult dogs (aged between 12–72 months) were categorized by weight into three groups: small breed (41 dogs), medium breed (51 dogs) and large breed (42 dogs), as shown in Table 1. Prior to admission to the study, health status was examined as described above.

Measurements: An outdoor pool was used for this experiment, with a water temperature between 30-35^{0}C. To prevent heart rate error from excitation, all animals were allowed to swim prior to collecting the data. The data was collected at the 5th swimming (result from experiment 1). The heart rate was measured using a pulse watch (CHF-100-1VDR, Casio) every minute for 30 minutes. Moreover, all animals' heart rates were measured three times, to serve as a normal heart rate for these experimental groups.

Statistical analysis: The heart rates of samples at every minute, from the 0th–34th minutes, were expressed as means. SPSS version 17 was used to analyze the model of mean heart rate of samples in conjunction with swimming times, using the CURVEFIT command. The significant level was set at $p<0.05$.

Results

Animal health

All dogs in the experiments were subjected to a complete health examination, including a blood evaluation and overall physical examination. Blood results from all animals were normal (data not shown). Physical examination; including body temperature, auscultation of lung and heart, mucus membrane evaluation, and capillary refill time, found no signs of abnormality.

Experiment 1

The average heart rate at each minute was calculated for 21 dogs (Fig 1). From observations during the experiment we found that most dogs showed excitement and nervous activity during their 3rd to 5th swimming. Heart rates during 10 minutes of swimming at the 1st to 4th swimming time were significantly higher ($p<0.05$) than at the 5th to 8th swimming. After the 5th time of swimming the heart rates showed a smooth increase (Fig 1). However, no significant differences ($p>0.05$) were observed between the 1st to 4th and the 5th to 8th swimming. Moreover, the correlation between time spent swimming (0-10 minutes) and heart rate at each time of swimming (1st to 8th time) were calculated and are as follows: 0.823, 0.688, 0.751, 0.729, 0.937, 0.935, 0.959 and 0.936, respectively.

Table 1 Dog profiles used in this study.

Size	Total	Sex: Female	Sex: Male	Age (months)	Weight (kg)	Heart rate (time/min)
Small	41	18	23	30±11	4.81±1.81 ^{a}	162±15 ^{a}
Medium	51	27	24	32±11	15.82±2.23 ^{b}	123±15 ^{b}
Large	42	22	20	34±10	30.79±4.96 ^{c}	95±16 ^{c}

Different superscripts (a,b,c) in same column are significantly different ($p<0.05$).

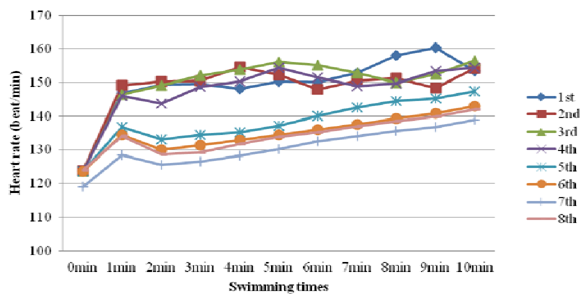

Figure 1 Mean heart rate change during 10 minute swimming each time (1st to 8th swimming)

Experiment 2

Common values were measured and compared between the three groups (small-, medium- and large-breed dogs). Weight and heart rate were significantly different (p<0.05) between groups, while age showed no significant difference (p>0.05), as shown in Table 1. Comparison of the heart rate between males and females in each group found a significant difference (p<0.05) for all sizes, and showed higher values in female dogs (Table 2). No correlation was found between age and heart rate, or weight and heart rate in all sizes of dogs, and overall as well (Table 2). To study the effect of age on heart rate, all dogs were categorized into four groups: less than 24 months of age, 25-36, 37-48, and over 48 months. The heart rates between groups were not significantly different (p<0.05). Moreover the correlation between age and heart rate in each group was calculated, a correlation was found only in the group over 48 months of age (Table 3).

Table 2 Comparative heart rate between genders and correlation between age, weight and heart rate in each group

	Comparative heart rate between genders			*Correlation of heart rate and*	
	Male	Female	*P*-value	Age	Weight
Small-size	158±20	166±14	0.0095	0.2192	0.1694
Medium-size	118±14	127±15	0.0002	-0.2291	-0.0525
Large-size	92±13	100±21	0.0039	-0.0203	0.0213
All sizes	124±32	129±31	0.0687	-0.1015	-0.7631

Table 3 Comparative heart rate between genders and correlation between age, weight and heart rate in each group

	Age (months)			
	< 24	25–36	37–48	> 48
Heart rate	125±32	131±30	123±36	114±33
Correlation coefficient	-0.1357	-0.2332	0.1547	0.5480

Table 4 Results of R, R-square, adjusted R-square, and standard error (SD) of the estimate for each breed group

Breed size	*R*	*R*-square	Adjusted *R*-square	SD of the estimate
Small	0.974	0.949	0.944	1.576
Medium	0.982	0.965	0.962	1.511
Large	0.988	0.977	0.975	1.178

Table 5 Coefficients, constant and significant level for each breed group

Breed size		Unstandardized coefficients		Standardized coefficients	*t*	*P* value
		B	Std. error	Beta		
Small	Time	1.085	0.248	1.677	4.372	<0.001
	$Time^2$	-0.034	0.017	-1.823	-1.961	0.059
	$Time^3$	0.001	0.000	1.156	1.968	0.058
	Constant	163.426	0.961		170.109	<0.001
Medium	Time	1.518	0.238	2.011	6.376	<0.001
	$Time^2$	-0.095	0.016	-4.423	-5.784	<0.001
	$Time^3$	0.002	0.000	3.481	7.209	<0.001
	Constant	124.640	0.921		135.269	<0.001
Large	Time	1.136	0.186	1.577	6.122	<0.001
	$Time^2$	-0.068	0.013	-3.296	-5.277	<0.001
	$Time^3$	0.002	0.000	2.780	7.051	<0.001
	Constant	97.028	0.718		135.117	<0.001

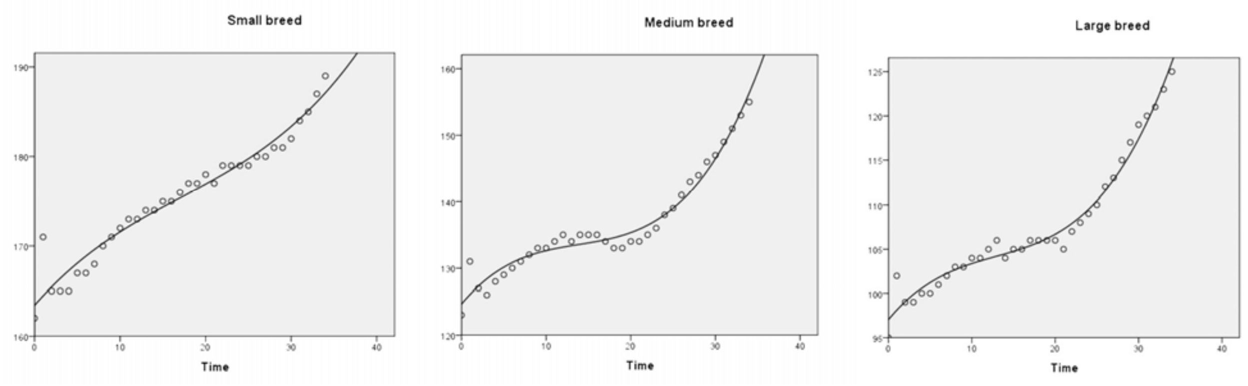

Figure 2 Scatter plot of mean heart rate of small-, medium- and large-breed group

Scatter plots of mean heart rates of different sizes of dogs at every minute, from the 0th to 34th minute, are shown in Fig 2. The CURVEFIT command (SPSS software, version 17) was used to determine the relationship between time and heart rate after swimming. The model shown was the result of analysis of various models. Linear, quadratic and cubic models were selected as proposed models; the cubic model was found to best fit the data. The R-square in each group of samples was close to 1, as shown in Table 4. The model built using the cubic model and the results are shown in Table 5. The model of the relationship between heart rate and time in small-, medium- and large-breed dogs are as follows: small breed; y=163.426+1.085x-0.034x2+0.001x3, medium breed; y=124.640+1.518x-0.095x2+0.002x3 and large breed; y=97.028+1.136x-0.068x2+0.002x3, when x=time and y=heart rate.

Discussion

This is the first report to show heart rate changes during aquatic exercise in dogs. Nowadays, rehabilitation in small animal medicine has become a much-discussed issue. However, the basic data in this field are still limited by the relatively low number of existing reports, which has made this information difficult to apply in clinical practice. Compared with human studies, which can measure all important data (Hall et al., 2004; Silvers et al., 2007), animal studies have been restricted due to the experimental materials used. The instruments for measuring respiration rate, blood pressure and oxygen consumption cannot be put underwater. So, thus far, we have been able to collect heart rate data only.

The results of this study show that canine body weight and age are not related to heart rate. This result is similar to the findings of previous studies which showed no correlation between heart rate and weight in normal healthy dogs (Ferasin et al., 2010; Lamb et al., 2010). However, when we compared heart rates between different sizes of dogs we found a significant difference (p<0.05): small-size dogs had the highest heart rate, while large-size dogs had the lowest. A study of the effects of activity and heart rate change (Marosb et al., 2008) found that the heart rate increased during periods of increased activity (walking) and was lowest during lying, while it did not differ between sitting and standing. At the same time, no changes in heart rate variability were found in the case of different body positions and walking. In contrast, heart rate variability significantly increased when dogs were oriented toward their favorite toy. We found a distinct individual characteristic heart rate change in this situation, compared to a similar body position without the toy being shown. Interestingly, during separation from the owner, the heart rate did not increase; but when a strange person was petting the dog, a significant increase in the heart rate was observed. However, the heart rate variability increased only when the petting was discontinued.

Some important parameters can affect heart rate. This study found heart rate to be affected by gender, with males showing a lower heart rate than female dogs. This result is similar to human studies which have found heart rates in males to be lower than in females (Opthof, 2000; Villareal et al., 2001). Human studies have determined that this difference is due to sexual hormones (Villareal et al., 2001).

Another important factor regarding heart rate is the animal's age. In our study, no significant difference was found between the heart rates of animals of 2, 3, 4, 5 and 6 years of age; moreover there was no correlation between age and heart rate. However, this factor does have an effect on heart rate in humans, especially young people (Opthof, 2000). Our study did not observe heart rates in dogs younger than 1 year or older than 7 years. Compared to previous studies (Ferasin et al., 2010), it was found that the age factor had an effect on heart rate only in younger dogs (less than 1 year old). This difference may result from changes in densities of specific membranes, different activities of gap junctions, and tissue fibrosis (Opthof, 2000).

Water temperature is another factor affecting heart rate. Previous studies showed higher heart rates during swimming in water with a temperature of 33^{0}C versus 27^{0}C or lower (Holmér et al., 1974; McArdle et al., 1976). Our study was done in water with a temperature between 30-35^{0}C to avoid this effect from water temperature. Higher water temperatures resulted in increased heart rate due to an increase in peripheral circulation from warmer water.

In the first period of swimming, dogs were excited, and fear of water activated their sympathetic nerves, resulting in increasing heart rates, as shown in experiment 1. After the 5th swimming, almost all animals could adapt to swimming, which reduced their excitement and nervousness. Because of this, their sympathetic nerve activity was down-regulated, resulting in smooth heart rate change. The results from experiment 1 were used in experiment 2, which focused on the heart rate change during swimming from aquatic exercise, not from nervousness. In experiment 2, all dogs were swiped 4 times before collecting data, which was done after the 5th swimming. However, in experiment 2 we also found that heart rates increased 1.0-1.5-fold during the 1st-2nd minute of swimming, compared to the normal heart rhythms before the animals got into the water. Based on the combined results of experiments 1 and 2, we believe that the increase in heart rates during the first few minutes in the water is due to excitement and nervousness of the animals in making the transition from land to water. After a few minutes, the heart rate changed smoothly and only slightly increased.

Not only heart rate can be used as a tool for designing a swimming program; peak oxygen uptake (VO_2) is also important for use by training programmers to estimate the intensity of exercise performed. While heart rate during exercise in humans has been studied on a population basis, allowing calculations adjusted for age and gender, such information is not available in dogs. The techniques and instruments used to measure VO_2 on land or during aquatic exercise in dogs are restricted for other animals as well. However, at the present time the authors of the present study are developing and testing additional techniques for measuring VO_2 in dogs.

In humans, therapeutic exercise for cardiovascular and metabolic endurance should continue for at least 20 minutes, 3-5 times per week, at submaximal exercise level. The target heart rate should be maintained at 70% of the maximum heart rate (HRmax) (Micheal, 2002; Wallace, 2006). However, among various breeds of dogs, different HRmax have been reported. For example, a typical mongrel dog has an HRmax of approximately 300 beats per minute, while that of a racing greyhound is 318 beats per minute (Wagner et al., 1977). Moreover, in human studies, communication can occur between trainer and patient, allowing patients to reveal when they feel they have reached their exercise limit, or are experiencing chest pain, high-frequency or difficulty in breathing, hypertension, fatigue or headache (Maddox et al., 2008). In dogs, the trainer can only observe the dog's behavior. For example, if the dog stops swimming, pants heavily or experiences difficulty in breathing, or shows signs of cyanosis, it means they are tried and not able to exchange enough oxygen which can lead to shock. However, in this study the dogs were not allowed to swim when those signs became apparent because it seemed to be dangerous for the animals. Our study found that 26 of the 134 dogs (19.4%) could not swim for 34 minutes. The first dog stopped swimming at 12 minutes, followed by 2, 2, 3, 3, 2, 3, 2, 2, 3 and 2 animals at 13, 14, 15, 16, 17, 18, 19, 20, 21 and 23 minutes, respectively. Based on our results, the dogs could swim for up to 34 minutes, and the swimming time could continue for at least 15 minutes.

In this experiment, a predictable heart rate equation was formulated using data from each group. This equation was based on heart rate changes during 34 minutes of swimming. We formulated three models for three different sizes of dogs, because we found the heart rate between groups to be significantly different. So, this equation could be used as a tool for predicting heart rate changes in dogs during swimming. However, future studies focusing on many additional aspects should be conduct, for example, oxygen consumption and blood pressure during swimming, and the effect of water temperature or water speed on changes of heart and respiration rates.

In conclusion, we believe that this study has important clinical applications. Clinicians could use this data for making decisions regarding an effective training program. Based on the results, we recommend that each time for swimming should be 15-30 minutes, depending on individual dog. This would require trainers to observe each dog to prevent over-exercise.

Acknowledgements

The authors are grateful to the Thailand Research Fund (MG5380026), the National Research University Project under Thailand's Office of the Higher Education Commission for financial support and the Faculty of Associated Medical Sciences, CMU budget for research funding. The authors express their gratitude and thanks to all staff members at the Bone and Joint Research Laboratory, Faculty of Veterinary Medicine, Chiang Mai University, and the Metta Animal Hospital, Muang, Chiang Mai, for their kind support.

The authors especially thank all dog owners for their kind support of dogs throughout this experiment. And many thanks to all clinicians, veterinary assistants and all students who generously provided their time for controlling the dogs in the pool.

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