CHAPTER IV

DISCUSSION

Study of $\dot{V}o_{2max.}$:

Exercise tests have been commonly used to evaluate cardiopulmonary functions. The $\dot{V}o_2max$ has become a widely utilized mean of assessing its upper limit of fitness (Legge and Banister, 1986; Klausen, et al., 1982). This test, first has been standardized by Taylor et al., (1955), who used a high initial work load with increasing rate every 3 minutes on a treadmill. Later, increased of work load in every 2 minute was used to predict $\dot{V}o_{2max.}$ (Shepard, 1987). The supine position cycle ergometer has been shown to result in lower $\dot{V}o_{2max.}$ than for treadmill tests (Fouke and Strohl, 1987), eventhough oxygen uptake increased as a linear function of time or work load both on the cycle ergometer and on treadmill test, (Astrand and Rodahl, 1986; Chick and Somet, 1988). Not only the important of the testing equipment but also the duration of testing. The previous study had reported that the optimal duration of test was approximately 8-17 minutes (Buchfuhrer, Hansen, Robinson, Sue, Wasserman and Whipp, 1983). In this study, the duration of 8-16 minutes was used and showed the highest value of $\dot{V}o_{2max.}$, therefore higher body temperature (Patton and Vogel, 1984; King, Costill, Fink, Hargreaves and Humans, 1985), greater dehydration (Smolander, Kolarip, Korhonen and Limarinen, 1986), different substrate utilization (Cartee and Farrar, 1988), subject discomfort and ventilatory muscle fatigue (Astrand and Rodahl, 1986) do not need to be considered. The tests were started before breakfast to eliminate postprandial energy expenditure (Welle, 1984) and finished before noon to avoid diurnal pattern of cardiac performance (Kostis, Moreyra, Amendo, Dipietro, Consgrove and Kou, 1982)

From table 2 the $\dot{V}o_{2max.}$ of 17-30 and 31-40 year-old aerobic-trained subjects were 60.61 ± 4.01 and 54.72 ± 5.26 ml/min/kg corresponded with the value of slow runner group that was 53.4 to 67.4 ml/min/kg which demonstrated by Sjodin and Svedengag (1985). They also agree with value of previous study of Coyle and his team (Coyle, Coggan, Hopper and Walters, 1988). The $\dot{V}o_{2max.}$ of 17-30 and 31-40 year-old untrained subjects were 44.86 ± 4.18 and 43-76 ± 7.97 ml/min/kg, also agree with previous study (Whipp and his team, 1981). The $\dot{V}o_{2max.}$ of 41-50 and more than 50 year-old aerobic-trained subjects were agree with values of 86 healthy men in the study of Dehn and Bruce (1972).

The $\dot{V}o_{2max.}$ of different aged groups of untrained subjects were not significantly different, while $\dot{V}o_{2max.}$ of aerobic-trained were significantly different (p value < 0.05 and $p < 0.001$) (Table 2). In young subjects $\dot{V}o_{2max.}$ were higher than the older ones. This result demonstrated that aging was affected by aerobic-trained which determined by $\dot{V}o_{2max.}$ In untrained groups, 17-30 and 31- 40 year-old did not show the statistically differences. Because of safety to untrained subjects who were older than 40 year-old, exercise test for $\dot{V}o_{2max.}$ in this group was not set. In addition, the $\dot{V}o_{2max.}$ in every aerobic-trained aged groups were higher than $\dot{V}o_{2max.}$ in all untrained groups. From these data, we could not say that aging effected the $\dot{V}o_{2max.}$ in human who were older than 40 year-old. We might say that $\dot{V}o_{2max.}$ was more suitable parameter to measure and use for classify the activities than the effect of age in human.

In fact, physical performance and $\dot{V}o_{2max.}$ declined with aging (Pollock, et al., 1987) and the changes might be decelerated by aerobic exercise training (Cartee and Farrar, 1987). It could be pointed out that there were correlation between the adaptation of cardiovascular, pulmonary system and exercising muscle (Verg, Seals, Hagberg and Holloszy, 1985). The $\dot{V}o_{2max.}$ might be preferentially correlated with the central circulation (Iwaokg, et al., 1988). So the optimal aerobic exercise that was used in our study could improve this system.

In contrast, previous studies had shown that there were no age-related changes in cardiac output, end-diastolic volume or end-systolic volume or ejection fraction at rest, and did not limit cardiac output per se in healthy subjects (Rodeheffer, Gerstenblish, Beard, Fleg, Becker, Weisfeldt and Lakatta, 1984; Mahler, Cunningham and Curfman, 1986). So the reduction in $\dot{V}o2_{max.}$ appeared to result from peripheral oxygen utilization rather than to cardiac causes such as increasing the stiffness of vascular wall (Walsh, 1987).

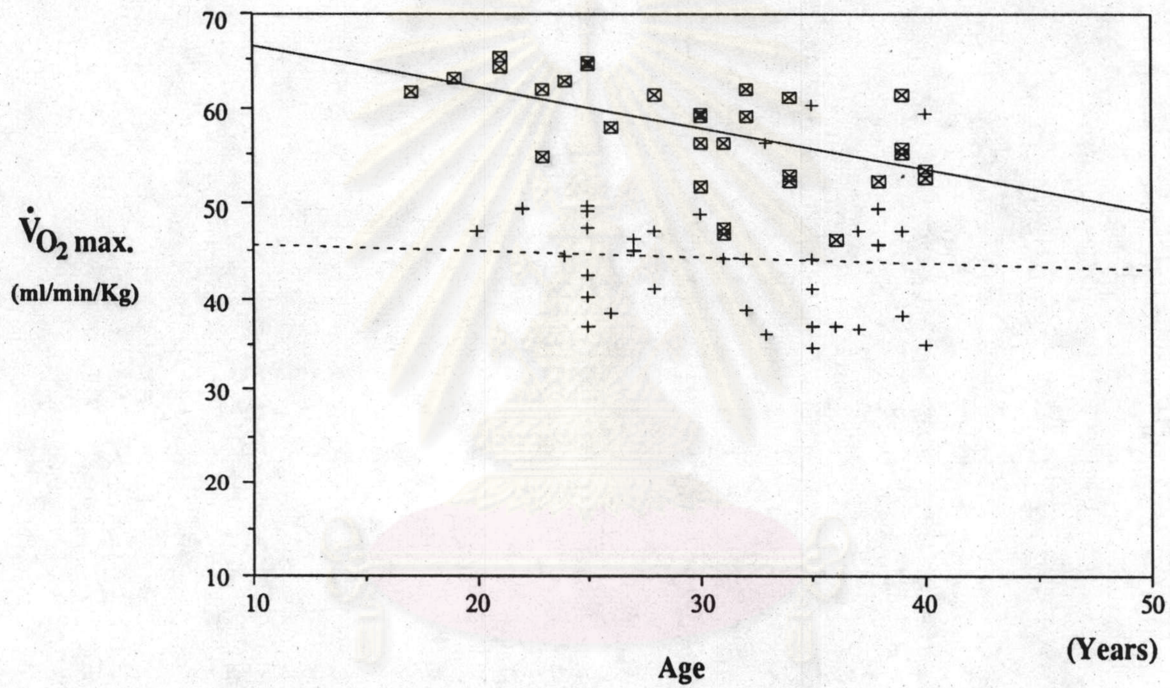
The progressive decline in $\dot{V}o2_{max.}$ with advancing age was greater in sedentary lifestyle associated with social norms, which might be due to the loss of muscle mass than in non-endurance trained ones (Shephard, Berridge, Montelpare, Daniel and Flowers, 1987). In this study, the lower $\dot{V}o2_{max.}$ with age agree with the studies in both human (Hagberg and co-workers, 1988) and rats (Cartee and Farrar, 1987). Cartee and Farrar (1988) suggested that these declinations might be due to the diminish of glycogen sparing or the reduction of cardiac output and less blood supplied to the exercised muscle. All these studies expressed the declining of $\dot{V}o2_{max.}$ as per kilogram body weight. So it might be concluded that the more sedentary lifestyle of living will bring the more declining in cardiopulmonary and muscular function.

Posner and co-workers (1987) measured $\dot{V}o2_{max.}$ in 171 (mean age = 68 year-old), compared with 44 (mean age = 39 year-old) health male showed the regression line of $\dot{V}o2_{max.}$ on age was Y = 49.81 - 0.34X, r = -0.77 ($p < 0.001$) (Posner, Gorman, Klein and Cline, 1987). Whereas Jones and his team stated that $\dot{V}o2_{max.}$ = 55 - 0.44 age, r = -0.71 ($p < 0.001$) (Jones, Mardrides, Hitchcook, Chypchar, McCartney, 1985). In our study the linear regression lines and regression correlations of the $\dot{V}o2_{max.}$ with age were defined for 31 aerobic-trained and 34 untrained subjects (age < 40 years) were Y = 70.80 - 0.44X, r = -0.53 ($p < 0.001$) and Y = 46.32 -

0.07X, $r = -0.06$ ($p < 0.001$), respectively (Figure 9). The linear regression correlations of this study were very low that might be due to $\dot{V}o_{2max.}$ data contained from only young subjects (17-40 year-old), and the number of subjects were not great enough to define the correlation with age.

Figure 10 showed the linear regression line and regression correlation of $\dot{V}o_{2max.}$ with age which was defined for 54 aerobic-trained subjects (17-74 year-old) was $Y = 74.33 - 0.58X$, $r = -0.86$ ($p < 0.001$). The slope of this linear equation is actually represented the rate of declining of $\dot{V}o_{2max.}$ per years. Because of higher coefficient correlation with age in this equation (-0.86), so we could stated that the slope was actually the rate of regression of $\dot{V}o_{2max.}$ with age, 0.58 ml/min/kg per year. This rate was agree with a decrease of $\dot{V}o_{2max.}$ of 0.56 ml/min/kg per year in active men (Dehn and Bruce, 1972). This rate was higher than previous studies which were 0.34 ml/min/kg per year (Posner et al., 1987) and 0.44 ml/min/kg per year (Jones et al., 1985). That might be due to our study the equation was only obtained from aerobic-trained subjects. Additional the differentiation of race, location, climate, nutrition and social norm of each countries.

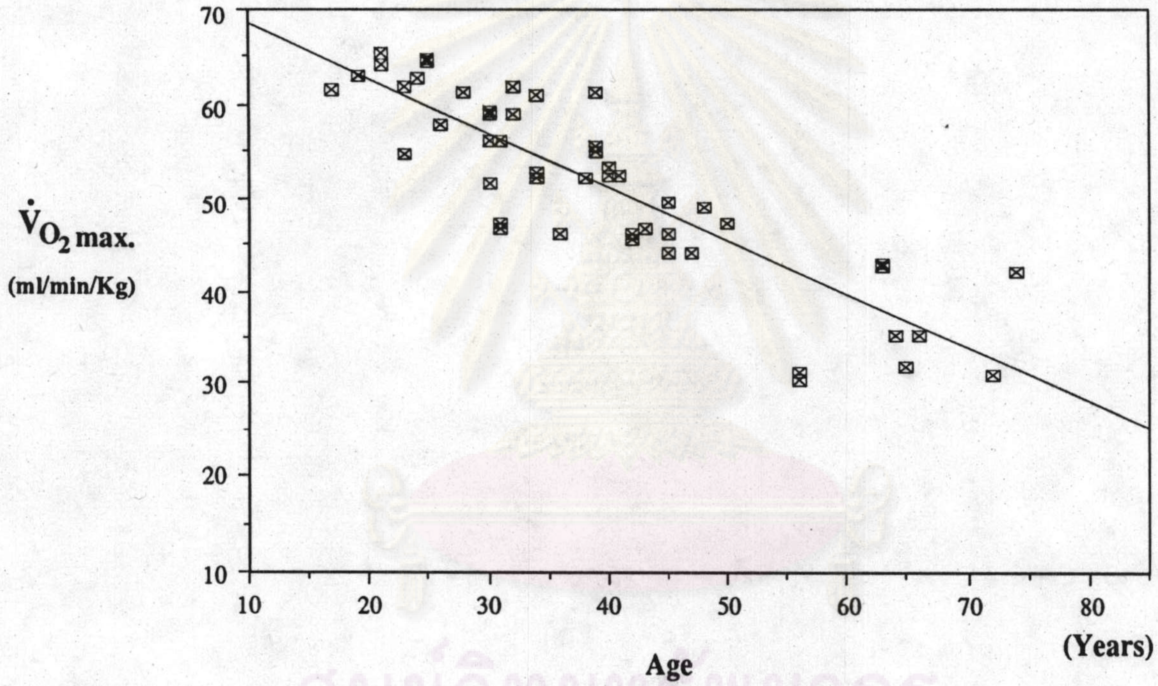
Figure 9. Values of maximal oxygen uptake ($\dot{V}_{O_2}max.$) of 34 untrained and 31 aerobic-trained subjects were plotted against age.



AEROBIC-TRAINED $Y = 70.80 - 0.44X$, $r = -0.53$, $p < 0.001$

UNTRAINED $Y = 46.32 - 0.07X$, $r = -0.06$, $p < 0.001$

Figure 10. Values of maximal oxygen uptake ($\dot{V}_{O_2max.}$) of 51 aerobic-trained subjects were plotted against age.



AEROBIC-TRAINED $Y = 74.33 - 0.58X$, $r = -0.86$, $p < 0.001$

<u>Study of Anaerobic threshold</u> :

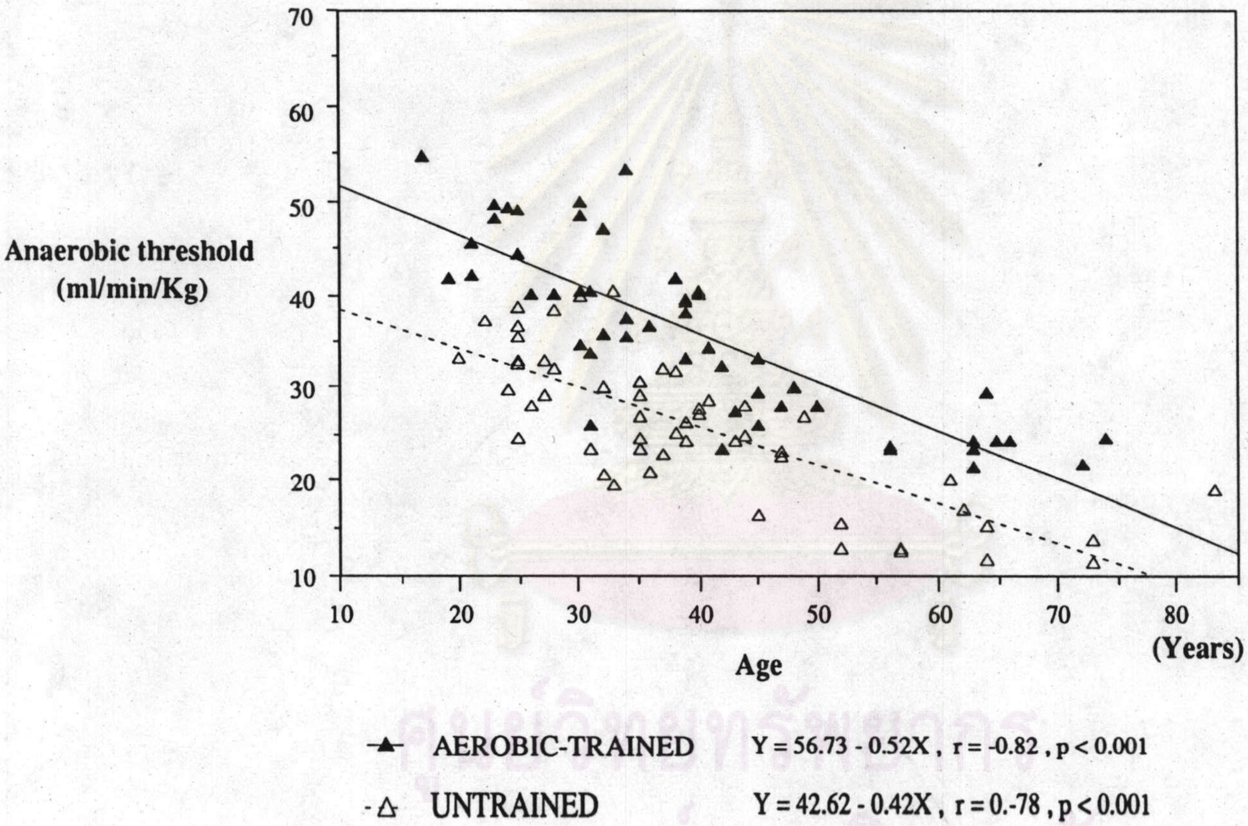
Our study from table 3 demonstrated that aerobic-trained groups showed higher anaerobic threshold than untrained groups which agree with previous studies done by Davis et al., 1979 and Tanaka and his team, 1984. This value also declined with age in the same as study of Allen and co-workers in 1985.

The anaerobic threshold in our study was higher than of obesity subjects in previous study (Tanaka, et al., 1987). The anaerobic threshold of untrained subjects was agree with anaerobic threshold in the study of Aunola and Rusko that was 25.28 to 39.26 ml/min/kg of 19-50 year- old subjects (Aunola and Rusko, 1986). It was also agree with 25.28 to 39.26 ml/min/kg of 23.5 ± 3.3 year-old subjects in the study of Boulay and his co-workers (Boulay, Lortie, Simoneau, Hamel, Leblanc and Bouchard, 1985). The anaerobic threshold of aerobic-trained subjects was lower than the one of canoeists. (Bunc, Heller, Sprynarow, Zdanowicz, 1986). This might be due to the difference of race of subjects, and types, and/or intensity of exercise.

The reduction in oxygen uptake at the ventilation threshold in elderly was stated by Seals and his co-workers (1984). Their study used the highest oxygen uptake before the oxygen began to increase without a corresponding increment in the ventilatory equivalent for carbon dioxide. They indicated that this declining was resulted by the limitation of the respiratory and hemoglobin oxygen transport system responded to facilitate tissue oxygenation in the elderly (Horvath and Borgia, 1984). The optimal aerobic exercise in our study might improve this peripheral system.

Posner and his team (1987) demonstrated that the regression line of anaerobic threshold with age was $Y = 21.58 - 0.083X$, $r = -0.48$ ($p < 0.001$). Whereas the linear regression lines and regression correlations in our study were $Y = 56.73 - 0.52X$, $r = -0.82$ ($p < 0.001$) and $Y = 42.62 - 0.42X$, $r = -0.78$ ($p < 0.001$) for aerobic-trained and untrained subjects, respectively (Figure 11). The slope of declining in anaerobic threshold for both aerobic-trained and untrained in present study were 0.52 and 0.42, respectively. Both values were higher than their report (0.083). This might be due to their linear correlation (r = 0.48) was very low, therefore, their linear equation could not suitably represent the relationship between anaerobic threshold and age. The different race, location, climate, nutrient associate with social norm of subjects were also encountered in the differentiation.

Figure 11. Values of anaerobic threshold of 53 untrained and 51 aerobic- trained subjects were plotted against age.



Study of oxygen uptake kinetics :

Two aerobic parameters that presented in this study had a great dependence on body weight that included both muscle mass and fat. So the body size was also an importance factor of fitness. More detailed mathematical models have been used to describe oxygen uptake kinetics, without additional indexing to body size (Sietsema et al., 1989) or diet influence (Hughson and Kowalchuk, 1981; McArdle, Katck and Katch, 1986).

The previous report that had demonstrated the heart rate responses showed a very rapid increasing from rest to work transition and slower responses in the work to work transitions (Hughson and Morrissey, 1982). So in this study, we set warm up period, at 0 watt, to eliminate this factor response.

The initial response of ventilation to exercise could be affected by a variation of work load used (Whipp and Wasserman, 1972). To avoid this factor, our study used relative work load of an individual's performance at 50% $\dot{V}o_{2max.}$ to set as a constant work load.

Oxygen uptake at steady state in this study achieved 65-90% of anaerobic threshold. Which might indicated that the appropriate intensity of exercise test which used in our study. Since Bason and his co-workers (1973) demonstrated that if the intensity of exercise was too high the graph of oxygen uptake would not reach it steady state, and it would higher than anaerobic threshold.

From table 4 the time constant of oxygen uptake kinetics at 50% $\dot{V}o_{2max.}$ (τ) of aerobic-trained subjects in this study was agree with the value $\tau = 49.1 \pm 7.8$ sec of 29.4 ± 7.3 year-old subjects in the study of Whipp and his colleagues (1981). Their study used ramp test and calculated the time constant (τ) by oxygen deficit and work efficiency. The result from our study was agree with the Casaburi and co-workers' study (1989) that was calculated the time constant by non-linear regression equation.

Both time constant (τ) of 17-30 year-old (Table 4) aerobic-trained and untrained subjects were agree with the value $\tau = 58.2 \pm 10.2$ sec of 19-20 year-old subjects in the study of Hughson and Morrissey (1982). They had set work load at about 80% of anaerobic threshold and collected the gas by 7 litters mixing chamber for calculation of oxygen uptake.

The values of time constant (τ) (Table 4) of aerobic-trained subjects who were older than 30 year-old were higher than the value reported by Casaburi and Colleagues (1977). In their study, they used 80% of anaerobic threshold and calculated the value breath by breath from digital computer.

The time constant (τ) of 77.02 ± 17.49 sec (Table 4) in untrained subjects who were older than 50 year-old was agree with the value $\tau = 74.4 \pm 5.8$ sec of 52.8 ± 1.7 year-old subjects in the previous study of Nery and colleagues (1985). They used breath by breath data for calculating their time constant (τ).

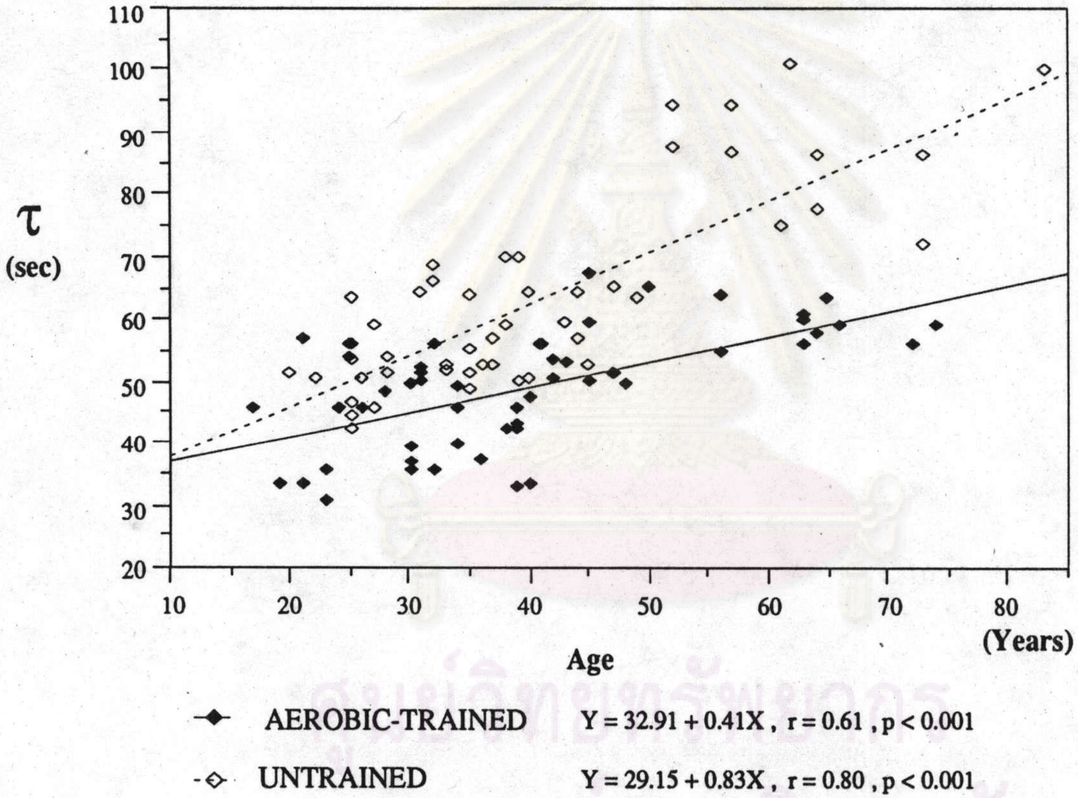
The time constants (τ) of 31-40 and more than 50 year-old aerobic-trained subjects were significantly higher than untrained subjects. These results were agree with idea of Hichson and co-workers (1978) that training could effect the value of the time constant (τ).

There were no significant difference between time constant values (τ) of aerobic-trained and untrained of 17-30 and 41-50 year-old subjects. These might be due to the standard deviation of these parameters were very high, so in the future the more numbers of subjects should be collected in this kind of study.

This finding could be explained by correlating   with the anaerobic threshold. Normally, the exercise muscle first uses energy storages which are intramuscular ATP and CP (Saltin, 1973). The limitation of these energy storages (Casaburi et al., 1989) is the key for exercised muscle to turn to produce energy from glycolysis. The end product of this process is lactic acid. The more lactic acid is continued to produce until the circulation to this exercised muscle is increased. More oxygen is supplied to the muscle. This exercised muscle could changed to aerobic process or called "Kreb's cycle". Astrand and Rodahl (1986) demonstrated that person who has prolonged aerobic exercise training could produce more the numbers of capillary to the active muscle. So in aerobic-trained muscle, there was more oxygen supplied than in untrained one. This idea suggested that τ, the time point that exercised muscle could turn to aerobic process, in aerobic-trained person should less than untrained subjects that shown in our study. Not only more oxygen supplied to active muscle in aerobic-trained person was increased but the accumulated lactic acid was also removed from the active muscle. Therefore, fatigue response will be less in the trained person than untrained person.

The result of oxygen uptake kinetics in figure 12 indicated that the linear regression lines and linear regression correlations with age of aerobic-trained and untrained subjects were $Y = 32.91 + 0.41X$, $r = 0.61$ ($p < 0.001$) and $Y = 29.15 + 0.83X$, $r = 0.80$ ($p < 0.001$), respectively. Many researchers have studied aerobic parameters in old age persons, but no one indicated any equations to represent the relationship between age and the time constant of oxygen uptake kinetics. So we could not compare these linear regression equations to any references. The slope of reduction in time constant of oxygen uptake kinetics at 50% $\dot{V}o_{2max}$. with age for both aerobic-trained and untrained subjects were 0.61 and 0.80, respectively. The declining of τ was only affected in aged untrained but was not reduced τ in trained ones. And the less value of slope produced by aerobic exercise might indicated another utility of aerobic exercise in helping to slow the effect of age on oxygen uptake mechanism. That mechanism might be due to the transport of oxygen at working muscle (Hughson and Morriesey, 1983), and/or oxygen demand of working muscle (Lynch and Paul, 1984).

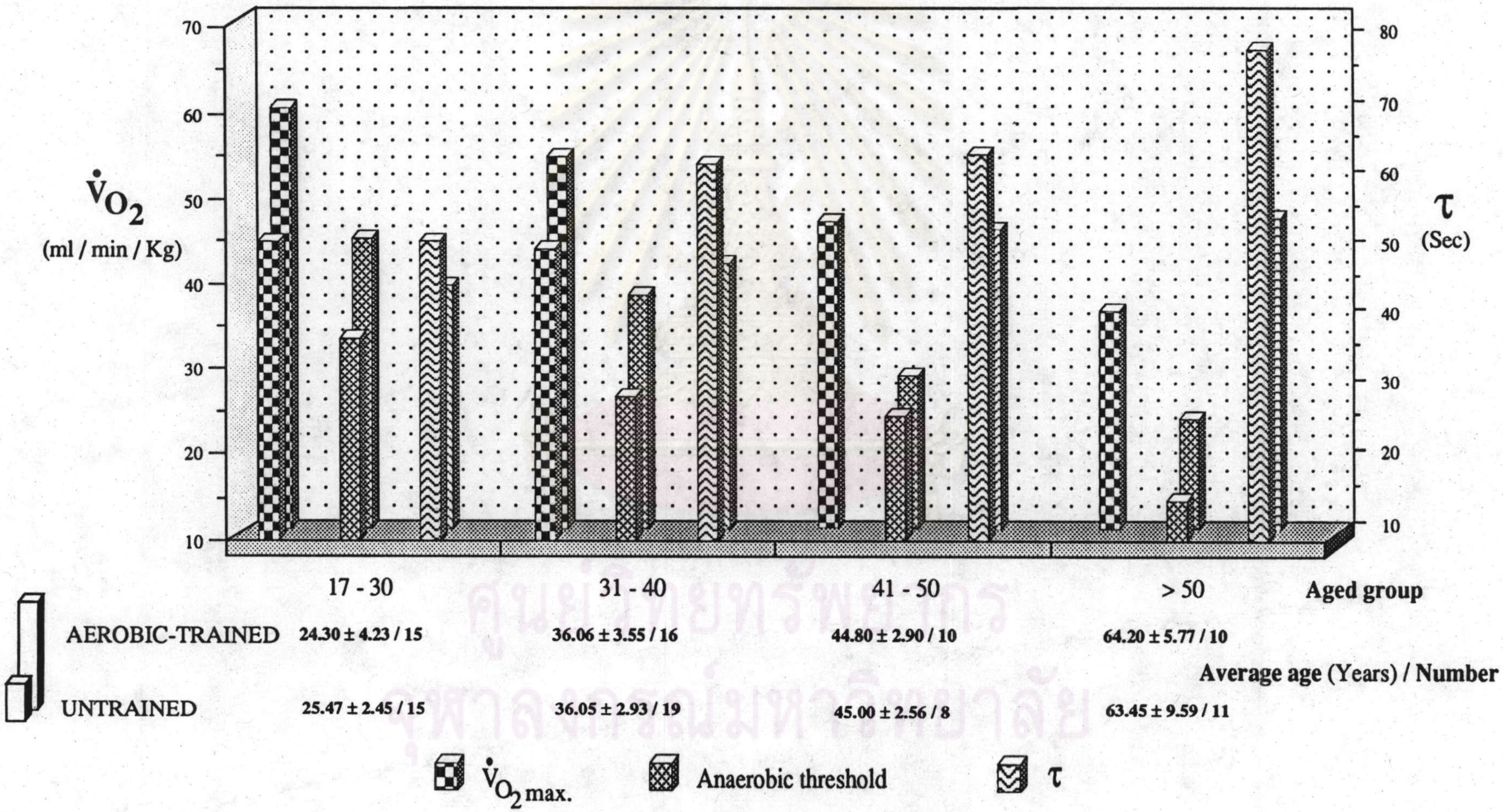
Figure 12. Values of time constant of oxygen uptake kinetics defined at 50% $\dot{V}O_2max.$ (τ) of 53 untrained and 51 aerobic-trained subjects were plotted against age.



<u>Conclusion</u>

In this study, we tried to determine physiological determinants of endurance capacity which were $\dot{V}o_{2max.}$, anaerobic threshold, and oxygen uptake kinetics. All these 3 parameters normally are declined by aging. The results of this study (Figure 13) have indicated that the optimal aerobic exercise could improve these declining processes in every aged level. Otherwise, the optimal aerobic exercise could improve the central and peripheral circulation and pulmonary function and being to the better cardiopulmonary performance which indicated by aerobic parameters.

Figure 13. Comparison means of maximal oxygen uptake ($\dot{V}O_{2max.}$) , means of anaerobic threshold, and means of time constant of oxygen uptake kinetics at 50% $\dot{V}O_{2max.}$(τ) in different aged groups between 53 untrained and 51 aerobic-trained subjects.



Suggestions for Further Study

The demonstration of age-related skeletal muscle change which include muscle mass and capillary density was another area to be interested. Aging process decreased the amount of intermyofibrillar mitochondrial protein, while aerobic training increased the mitochondrial protein, which was the major part of oxidative metabolism (Farrar, Martin and Ardies, 1981; Dudley, Abraham, Terjung, 1982). Another demonstration stated that the loss of oxidative capacity and myoglobin concentration of skeletal muscle of rat with age could be restored by endurance exercise (Beyer and Fattore, 1984). Fleg and Lakatta demonstrated by creatinine excretion and stated that a large portion of the age-associated decline in $\dot{V}o2_{max.}$ in non-endurance trained was explicable by the loss of muscle mass which was observed with advancing age (Fleq and Lakatta, 1988).

Our study could demonstrate that $\dot{V}o2_{max.}$, anaerobic threshold and τ were declined by aging and optimal aerobic exercise could decelerate this effect. We purposed the idea that it might be due to an aerobic exercise could improve cardiovascular function and increase the numbers of capillary in an aerobic-trained muscle. So the different levels of blood supply to exercised muscle and the transport of oxygen or carbon dioxide in age trained and untrained are interesting.

This cross-sectional study showed that three aerobic parameters were higher in aerobic exercise male. We determined the declining rate of these parameters with ages of aerobic-trained and untrained Thai male. The longitudinal studies need to be further investigation to establish norm of aerobic parameters in Thai people. However, the correlation of norm with nutritional status, occupations and levels of exercise should be done.

<u>Obstacle</u>

The direct measurement of $\dot{V}o_{2max.}$ is a little discomfort for most subjects. The exhaustion at the end of the test need some cheer-up for continuing of the best results. Due to this study is not safe for age untrained over 40 year-old, the cardiologist or physician have to stand by during the test. The EKG need to be recorded through out the test for detection and prevention of cardiac hazard. The real information for each subjects is very important before the test. The criterias to terminate exercise test are kept in mind of researchers. The most important thing to remember is that we must be careful about the safety of our subjects.

In general, the $test_1$ and the $test_2$ cannot be completed in one day. However, both of the tests must finish in the same week or not longer than 7 days, because of the time interval must effect the accuracy of results.