RESULTS

The results were reported orderly in 4 separated parts as follows : 1) the growth rate 2) the serum thyroid hormone concentrations 3) the muscle weights and 4) the contractile properties of the muscle.

Part I. Growth Rate

The body weights during experimental period of 4 groups are presented in Table 1 and graphically depicted in Figure 4. The initial body weights were almost similar for the experimental and control groups. In group I, the mean body weight was 271.5±2.5 g at week 0 and increased to 443.0±10.5 g (about 63.2 %) at the end of the experimental period. In group II, the mean body weight was 267.0±3.0 g at week 0 and increased to 401.5±4.6 g (about 50.4 %) at the week 12. It was found that the mean body weight in group II was significantly lower ($P<0.05$) than that obtained from group I, at weeks 2, 4, 6, 8, 10 and 12, respectively. In group III, the initial mean body weight (262.0±4.1 g) was significantly lighter ($P<0.05$) than that observed in group I. However, the mean body weight at week 6 (before entry into exercise training from weeks 7-12) between groups I and III (393.0±12.1 g in group I, 369.5±11.6 g in group III) was not significantly different ($P>0.05$). Through the 6 weeks of swimming exercise, the weight gain in group III, about 7.2 % (from 369.5±11.6 g to 396.0±7.6 g), was apparently lower than that observed in group I, about 12.7 % (from 393.0±12.1 g to 443.0±10.5 g). Correspondingly, the mean body weights at weeks 8, 10 and 12 in group III were significantly lower ($P<0.05$) than the values obtained from group I. In group IV, the mean body weight was 358.0±9.5 g

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Table 1 Mean body weights(g) of 4 experimental groups (n = 10 each).

Group	Time (week)						
	0	2	4	6	8	10	12
I	271.5 ± 2.5	334.5 ±6.0	368.0 ± 8.9	393.0 ±12.1	413.0 ±5.4	430.0 ±10.2	443.0 ±10.5
II	267.0 ± 3.0	310.0* ±7.3	344.0* ± 5.5	363.5* ±6.0	370.0* ±5.8	379.0* ±5.4	401.5* ±4.6
III	262.0* ± 4.1	316.0 ±10.1	344.5 ±13.8	369.5 ±11.6	385.0* ±10.0	389.0* ±9.6	396.0* ±7.6
IV	267.0 ± 4.7	316.0 ±10.5	345.5 ±8.6	358.0 ±9.5	352.5 ±10.4	364.0 ±9.6	375.0** ±8.4

* $P < 0.05$ between groups I and II, I and III

** $P < 0.05$ between groups II and IV

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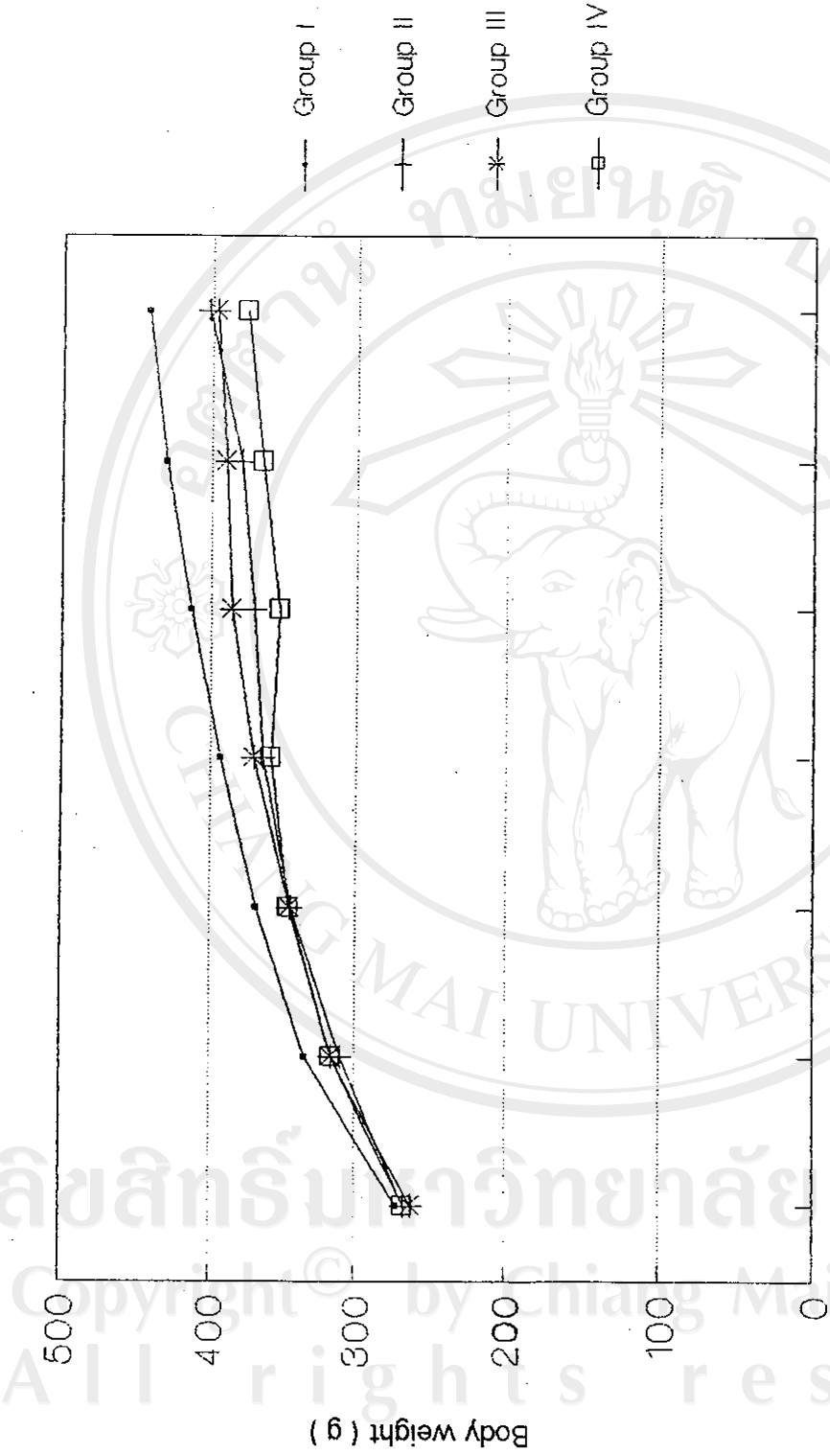

Figure 4 Comparison of body weights among 4 experimental groups.

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at week 6 and increased to 375.0±8.4 g (about 4.7 %) at week 12. It seemed that the weight gain during exercise in group IV was slightly lower than that noted in group III eventhough no significant difference (P>0.05) in mean body weight was observed. The increment of body weight during 6 weeks of exercise training in group IV was markedly lesser than that note in group II (10.4 %, from 365.5±6.0 g to 401.5±4.6 g). In addition, the mean body weights at weeks 8, 10 and 12 in group II were likely greater than those observed in group IV, although the significant difference (P<0.05) was observed only at week 12.

The degree of obesity of the animals was determined by obesity index which was calculated from the relationship between naso - anal length and body weight as previously described. Table 2 and Figure 5 represent the obesity indexes of 4 experimental groups. The obesity indexes during the entire period of the experiments in 4 groups were in the range of 0.290 - 0.299 and no significant difference (P>0.05) of these obesity indexes was found among the 4 experimental groups.

Part II. Serum Thyroid Hormone Concentrations.

In order to determine the thyroid status, the serum concentrations of thyroid hormones both triiodothyronine (T_3) and tetraiodothyronine or thyroxine (T_4) were measured. The mean serum T_3 concentrations of 4 experimental groups are summarized in Table 3 and graphically demonstrated in Figure 6. In group I, the serum concentrations of T_3 were 151.1±6.9 ng/dL at the control week 0 and 134.4±6.3, 140.9±3.5 and 126.4±8.5 ng/dL at weeks 4, 8 and 12, respectively. The significant difference (P<0.05) in the serum T_3 levels in group I

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Table 2 Mean obesity indexes of 4 experimental groups (n = 10 each).

Group	Time (week)						
	0	2	4	6	8	10	12
I	0.297 ±0.005	0.301 ±0.005	0.296 ±0.003	0.296 ±0.003	0.292 ±0.002	0.294 ±0.002	0.292 ±0.002
II	0.294 ±0.002	0.297 ±0.002	0.299 ±0.001	0.295 ±0.002	0.295 ±0.002	0.294 ±0.001	0.295 ±0.002
III	0.297 ±0.003	0.297 ±0.003	0.293 ±0.004	0.293 ±0.003	0.293 ±0.002	0.292 ±0.001	0.289 ±0.002
IV	0.298 ±0.002	0.295 ±0.002	0.295 ±0.003	0.297 ±0.003	0.290 ±0.003	0.291 ±0.002	0.290 ±0.002

$P > 0.05$

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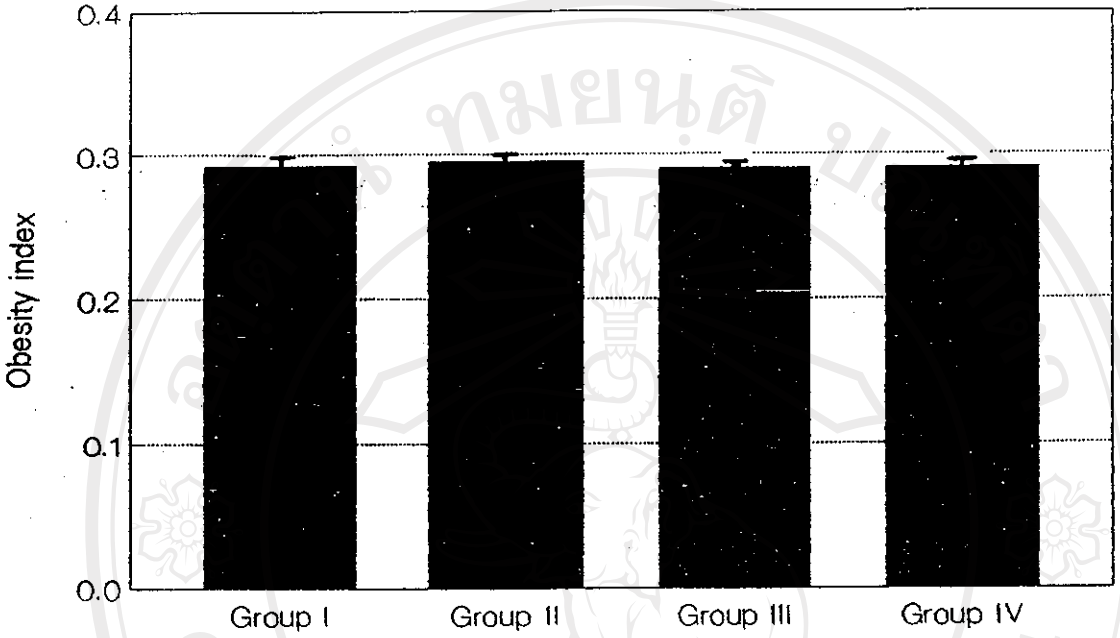

Figure 5 Comparison of obesity indexes among 4 experimental groups.

$P > 0.05$

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Table 3 Mean serum T_3 concentrations of 4 experimental groups (n = 10 each).

Group	Mean serum T_3 concentration (ng / dL)			
	Week 0	4	8	12
I	151.1 ± 6.9	134.4 ± 6.3	140.9 ± 3.5	126.4 ± 8.5 $^{\circ}$
II	137.1 ± 5.5	101.1 ± 8.9 $^{\circ,*}$	73.1 ± 5.0 $^{\circ,*}$	73.1 ± 4.3 $^{\circ,*}$
III	147.1 ± 10.3	129.4 ± 8.8	118.7 ± 4.6 $^{\circ,*}$	110.8 ± 6.8 $^{\circ}$
IV	143.7 ± 3.8	102.4 ± 4.6 $^{\circ,+}$	75.3 ± 4.2 $^{\circ,+}$	78.4 ± 3.1 $^{\circ,+}$

$^{\circ}$ $P < 0.05$ from week 0

* $P < 0.05$ between groups I and II, I and III

\+ $P < 0.05$ between groups III and IV

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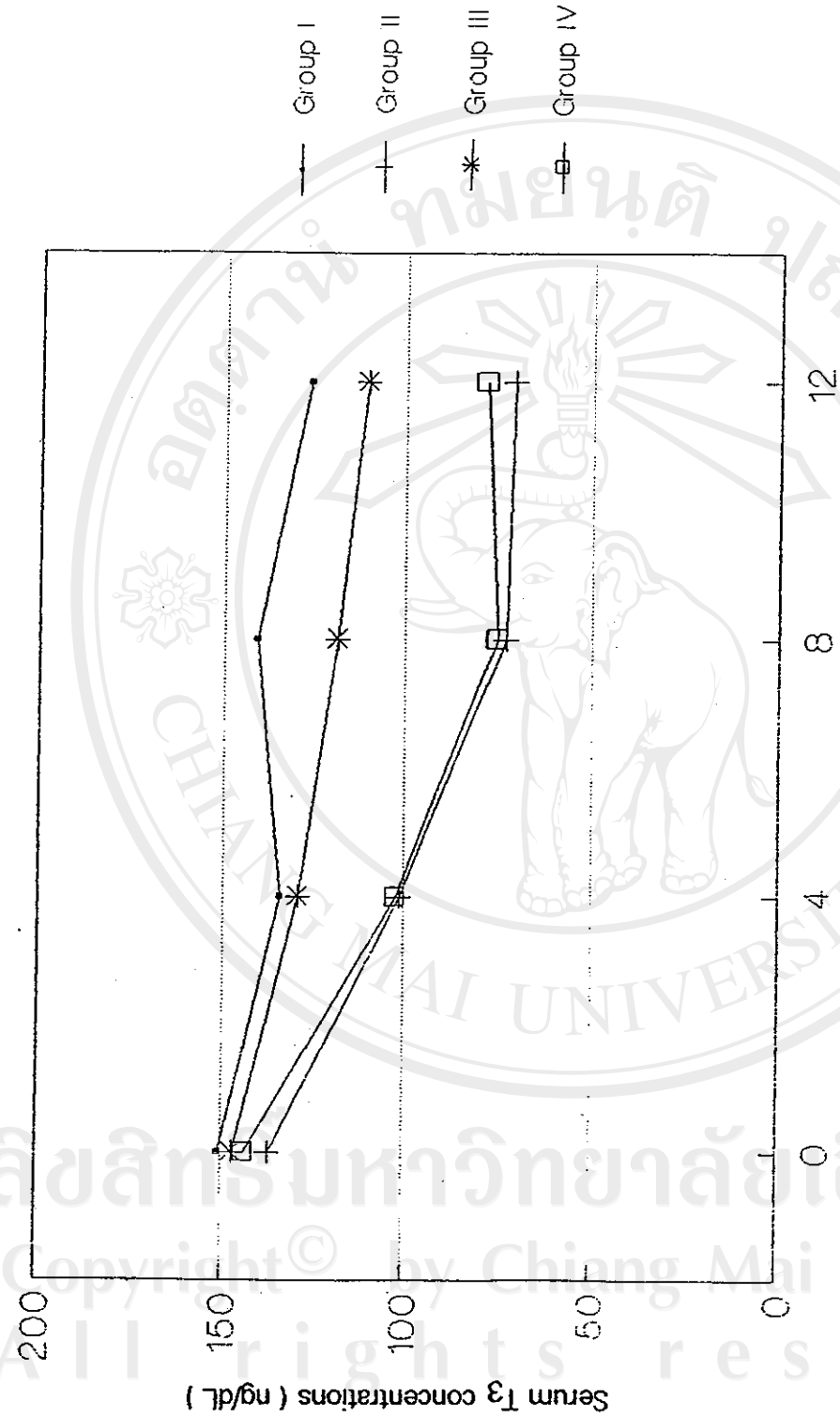

Figure 6 Comparison of serum T_3 concentrations among 4 experimental groups.

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was observed between weeks 0 and 12 . PTU administration was extremely effective in suppressing the circulating levels of T_3 . The serum T_3 concentration in group II was 137.1±5.5 ng/dL at the control week 0 and significantly decreased ($P<0.05$) to 101.1±8.9, 73.1±5.0 and 71.3±4.3 ng/dL at weeks 4, 8 and 12, respectively. The decrement of serum T_3 levels at weeks 4, 8 and 12 in group II was also found to be significant difference ($P<0.05$) from those observed in group I. The results obtained from group III showed an apparent decrease in the circulating levels of T_3 during exercise period (weeks 7 - 12) and the serum T_3 concentrations at weeks 8 and 12 (118.7±4.6 and 110.8±6.8 ng/dL) were significantly lower ($P<0.05$) than the control value at week 0 (147.1±10.3 ng/dL). In addition, the serum T_3 level during exercise training in group III seemed to be lower than the value noted in group I although the difference was statistically significant ($P<0.05$) only at the week 8. As a result of PTU administration, the circulating levels of T_3 before and during exercise period in group IV were profoundly suppressed. The serum T_3 concentration at the control week 0 was 143.7±3.8 ng/dL, being significantly greater than those noted at weeks 4, 8 and 12 (102.4±4.6, 75.3±4.2 and 78.4±3.1 ng/dL, respectively). The significant difference ($P<0.05$) in the decrement of the serum T_3 levels at weeks 4, 8 and 12 was also found between groups III and IV. When compared between groups II and IV, however, no significant difference ($P>0.05$) in the serum concentrations of T_3 at any week of the experiment was noted.

The values in Table 4 represent the mean serum T_4 concentrations of 4 experimental groups. In group I, the circulating level of T_4 almost had not significantly changed during the entire period of experiment. The serum T_4 concentrations were 4.4±0.3, 4.2±0.3, 4.0±0.4 and 3.7±0.2 ug/dL at weeks 0,

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4, 8 and 12, respectively. In group II, as a result of PTU administration, the circulating T_4 level was markedly depressed. Therefore, the serum T_4 concentration at the control week 0 (4.8±0.3 ug/dL) was significantly greater than those measured at 4, 8 and 12 (0.9±0.1, 0.7±0.1 and 0.6±0.1 ug/dL, respectively). Additionally, the significant difference ($P<0.05$) in serum T_4 levels was found between groups I and II at weeks 4, 8 and 12. In group III, there was an insignificant decrease ($P>0.05$) in the circulating level of T_4 during exercise training. The control serum T_4 level was in the range of 4.5±0.4 - 4.7±0.4 ug/dL, then it slightly changed to 4.2±0.4 and 4.0±0.3 ug/dL at weeks 8 and 12, respectively. In group IV, the serum T_4 concentration was 5.0±0.2 ug/dL at week 0 and significantly decreased during PTU administration to 0.7±0.1, 0.8±0.2 and 0.6±0.1 ug/dL at weeks 4, 8 and 12, respectively. During exercise period from weeks 7 to 12, there was a significant difference ($P<0.05$) in the serum T_4 levels between groups III and IV. However, when compared with group II, the serum T_4 concentrations at weeks 8 and 12 in group IV were not significantly different ($P>0.05$) from each other. Figure 7 illustrates the comparison of serum T_4 concentrations among 4 experimental groups.

Part III. Muscle Weights

Table 5 summarizes the weights of soleus muscles which are represent as the total weight (mg) and weight per 100 g of body weight (mg/100 g BW) of 4 groups. The average total weight of soleus in group I (165±6.8 mg) was signicantly greater ($P<0.05$) than those noted in groups II and III, (138±3.1,

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Table 4 Mean serum T_4 concentrations of 4 experimental groups (n = 10 each).

Group	Mean serum T_4 concentration (ug / dL)			
	Week 0	4	8	12
I	4.4 ± 0.3	4.2 ± 0.3	4.0 ± 0.4	3.7 ± 0.2
II	4.8 ± 0.3	0.9 ± 0.1 °,*	0.7 ± 0.1 °,*	0.6 ± 0.1 °,*
III	4.5 ± 0.4	4.7 ± 0.4	4.2 ± 0.2	4.0 ± 0.3
IV	5.0 ± 0.2	0.7 ± 0.1 °,+	0.8 ± 0.2 °,+	0.6 ± 0.1 °,+

° $P < 0.05$ from week 0

* $P < 0.05$ between groups I and II

\+ $P < 0.05$ between groups III and IV

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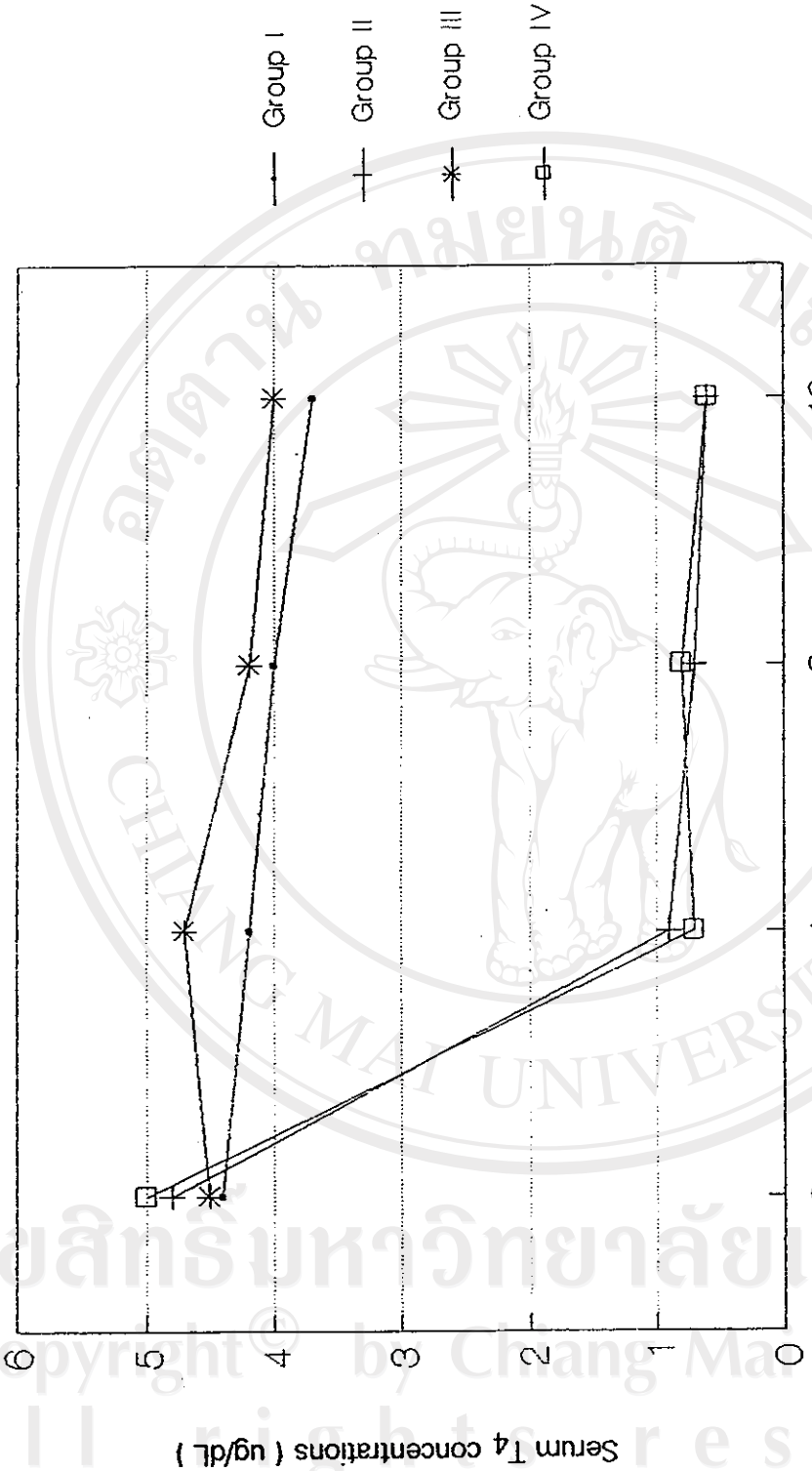

Figure 7 Comparison of serum T_4 concentrations among 4 experimental groups.

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144±3.6 mg, respectively). However, there was no significant differences ($P>0.05$) in the soleus weight (mg/100 g BW) between groups I and II (37.3±5.8 and 33.6±6.6 mg/100 g BW) or between groups I and III (37.3±5.8 and 36.0±8.1 mg/100 g BW). In group IV, the soleus weight was 139±4.1 mg or 37.2±7.8 mg/100 g BW. Both total weight and normalized weight of soleus muscle in group IV were not significantly different ($P>0.05$) from those observed in groups II or III. The histogram in Figure 8 represents the normalized weights of soleus muscles among the 4 experimental groups.

The average weights of plantaris muscles, total weight (mg) or normalized weight (mg/100 g BW) in groups I, II and III were 379±11.6 mg or 85.7±2.7 mg/100 g BW, 335±7.2 mg or 81.5±1.7 mg/100 g BW and 361±7.7 mg or 90.3±2.6 mg/100 g BW, respectively (Table 6). The total weight of plantaris muscle in group I was significantly greater ($P<0.05$) than those observed in groups II or III. However, when normalized weights were compared, no significant difference ($P>0.05$) was observed. In group IV, the weight of plantaris muscle was 315.0±5.8 mg or 84.7±2.6 mg/100 g BW. Although the total weight of plantaris muscle in group IV was significantly lower ($P<0.05$) than those noted in groups II and III. However, the significant differences in the normalized weights of plantaris between groups II and IV, and groups III and IV were not noted ($P>0.05$). The normalized weights of plantaris muscles in 4 experimental groups are graphically illustrated in Figure 9.

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Table 5 Mean weights of the soleus muscles of 4 experimental groups (n = 9 each).

Group	Mean soleus muscle weight	
	mg	mg / 100 g BW
I	165 ± 6.8	37.3 ± 5.8
II	138 ± 3.1*	33.6 ± 6.6
III	144 ± 3.6*	36.0 ± 8.1
IV	139 ± 4.1	37.2 ± 7.8

* $P < 0.05$ between groups I and II, I and III

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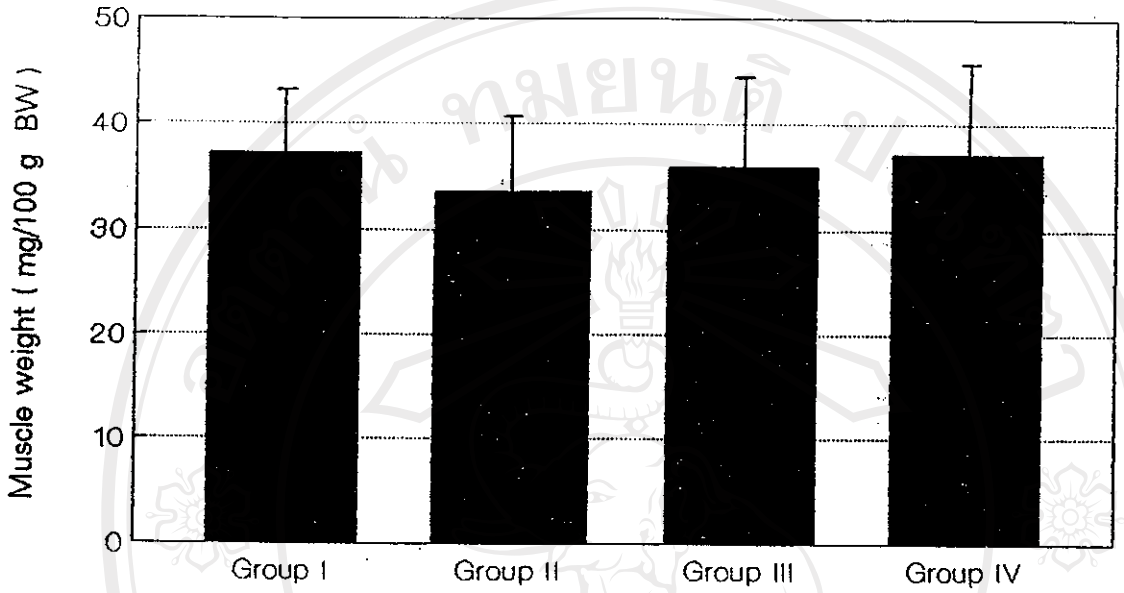

Figure 8 Comparison of soleus muscle weights among 4 experimental groups.

$P > 0.05$

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Table 6 Mean weights of the plantaris muscles of 4 experimental groups (n = 9 each).

Group	Mean plantaris muscle weight	
	mg	mg/ 100 g BW
I	379 ± 11.6	85.7 ± 2.7
II	335 ± 7.2*	81.5 ± 1.7
III	361 ± 7.7*	90.5 ± 2.6
IV	315 ± 5.8**,+	84.7 ± 2.6

* $P < 0.05$ between groups I and II, I and III

** $P < 0.05$ between groups II and IV

\+ $P < 0.05$ between groups III and IV

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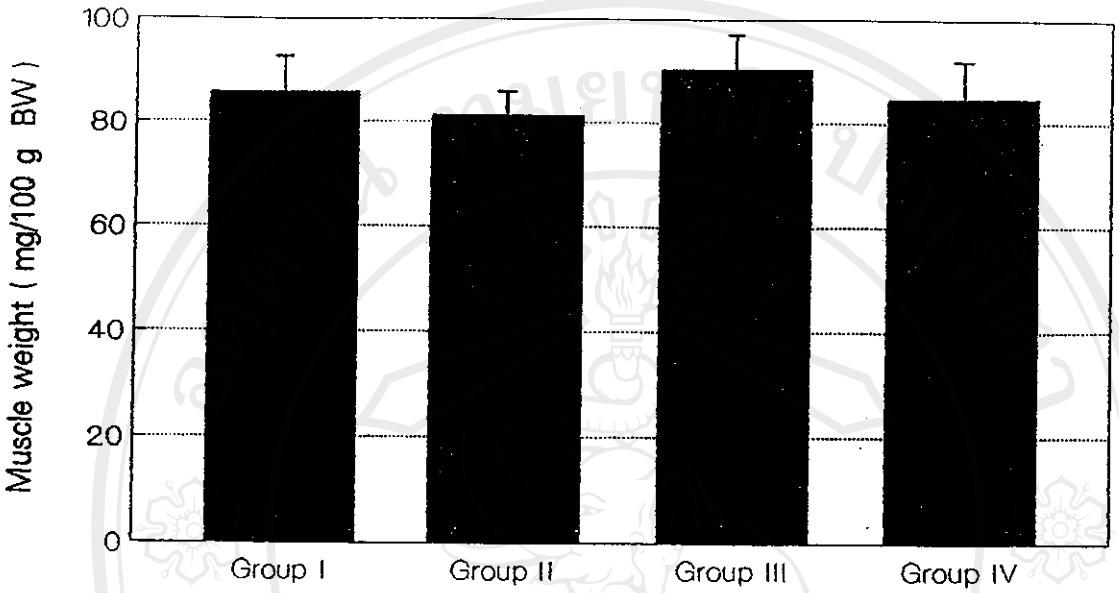

Figure 9 Comparison of plantaris muscle weights among 4 experimental groups.

$P > 0.05$

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Part IV. Contractile Properties of the Muscles

The typical isometric twitches which were recorded from the control, hypothyroid, exercise and hypothyroid - exercise soleus muscles are depicted in Figure 10. As illustrated in Table 7, the average isometric twitch tensions of soleus muscles represent an absolute twitch tension (g) and normalized twitch tension (g/g tissue) in groups I, II and III were 33.5±1.8 g or 210.8±16.2 g/g tissue, 27.7±0.6 g or 201.8±7.1 g/g tissue and 32.9±1.1 g or 233.2±7.3 g/g tissue, respectively. The absolute twitch tension of soleus in group I was significantly greater ($P<0.05$), about 20.9 %, than the value noted in group II. However, when expressed as normalized twitch tension, the increment was not large enough to be statistically significant ($P>0.05$). When compared with the control group (group I), the absolute and normalized twitch tensions of the soleus muscles in group III were not significantly different ($P>0.05$). The twitch tension of soleus in group IV was 29.1±0.9 g or 210.6±8.8 g/g tissue. Likewise, there were no significant differences ($P>0.05$) in both absolute (g) and normalized (g/g tissue) twitch tensions of the soleus muscles between groups II and IV, and between groups III and IV. The histograms in Figure 11 demonstrate the comparison of normalized twitch tensions (g/g tissue) of the soleus muscles among 4 experimental groups.

Table 8 presents the mean time to peak tensions (TPTs) of isometric twitches of the soleus muscles in 4 experimental groups. As a result of hypothyroidism, the TPT of isometric twitch of the soleus in group II was 33.9±1.9 ms, being significantly prolonged ($P<0.05$) when compared with that observed in group I (27.5±0.7 ms). The mean TPTs of isometric twitches of the soleus muscles were 29.2±1.9 ms in group III and 30.0±0.7 ms in group IV. These

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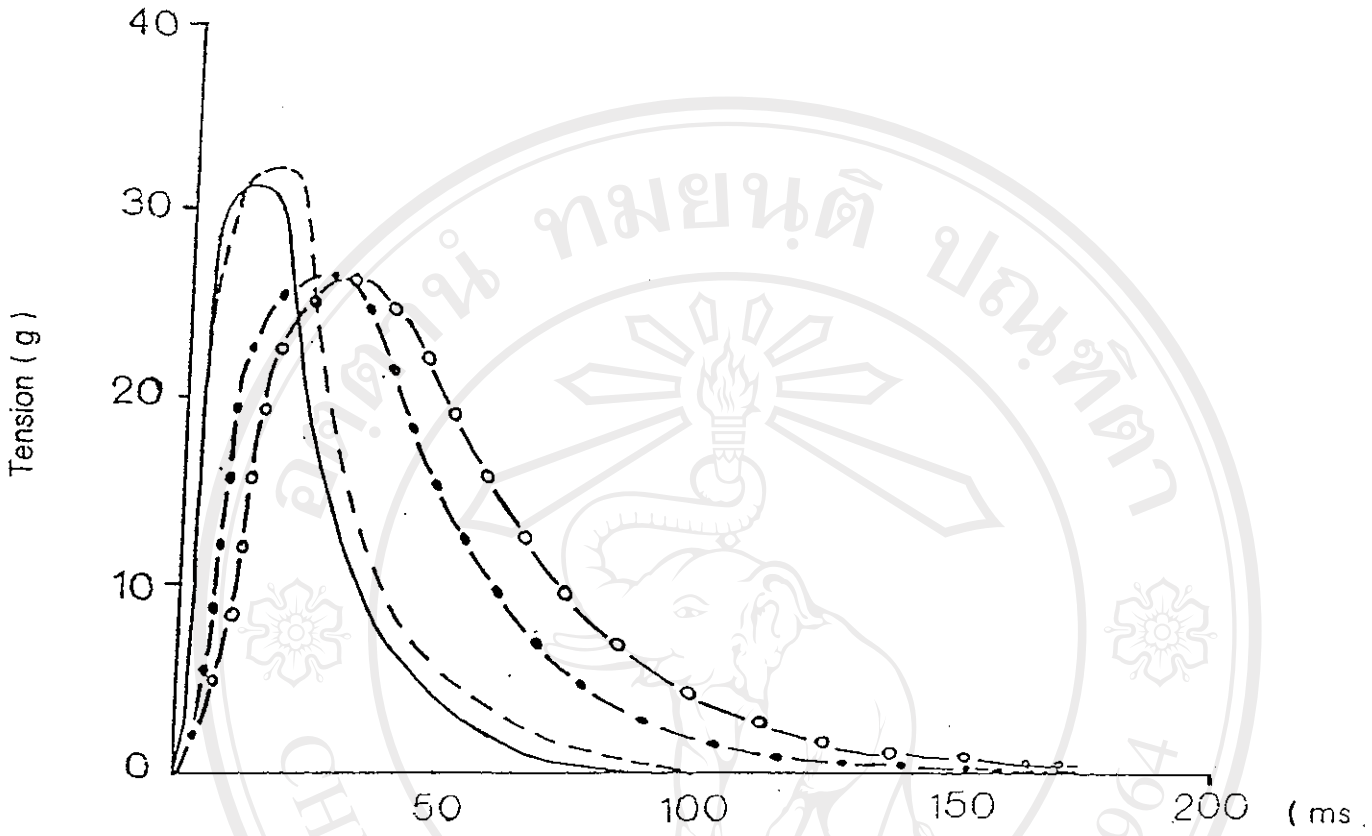

Figure 10 Typical examples of isometric twitches from control (———), hypothyroid (—— o ——), exercise (– – – –) and hypothyroid - exercise (—— • ——) soleus muscles.

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Table 7 Mean isometric twitch tensions of soleus muscles of 4 experimental groups (n = 8 each).

Group	Mean absolute twitch tension (g)	Mean normalized twitch tension (g / g tissue)
I	33.5 ± 1.8	210.8 ± 16.2
II	27.7 ± 0.6*	201.8 ± 7.1
III	32.9 ± 1.1	233.2 ± 7.3
IV	29.1 ± 0.9	210.6 ± 8.8

* $P < 0.05$ between groups I and II

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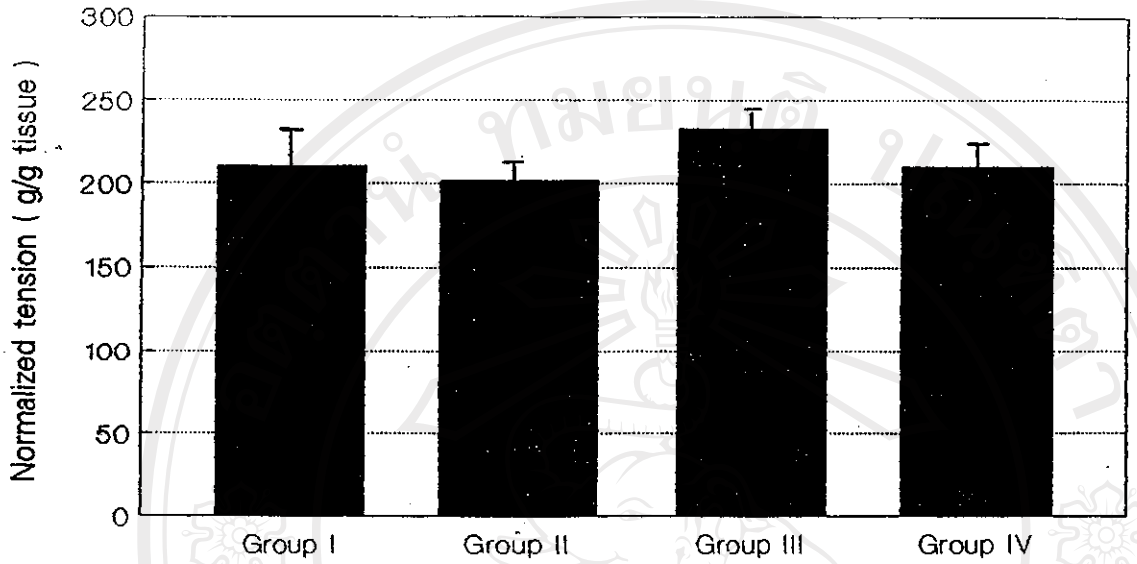

Figure 11 Comparison of isometric twitch tensions of soleus muscles among 4 experimental groups.

$P > 0.05$

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values were not significantly different (P>0.05) from each other. When compared with the result obtained from group II, the TPT of isometric twitch of the soleus in group IV was slightly decreased. However, the significant difference (P>0.05) between those two groups was not observed. The histograms in Figure 12 depict the comparison of the mean time to peak tensions (ms) of isometric twitches of the soleus muscles among the 4 experimental groups.

As shown in Table 9, the mean one - half relaxation times (1/2 RT) of isometric twitches of the soleus muscles in groups I, II and III were 21.7±1.0, 38.1±4.4 and 28.1±1.0 ms, respectively. The 1/2 RT of isometric twitch of the soleus in group I was significantly shorter (P<0.05) than those noted in groups II and III. In group IV, the 1/2 RT of isometric twitch of the soleus was 28.2±1.0 ms, being nearly identical to that observed in group III (28.1±1.0 ms). When compared with the result obtained from group II, the 1/2 RT of isometric twitch of the soleus in group IV was apparently decreased, although no significant difference was observed (P>0.05). The comparison of mean 1/2 RT of isometric twitches of the soleus muscles among the 4 experimental groups is graphically demonstrated in Figure 13.

In order to assess the force - frequency relationship of the soleus muscle, the muscle was stimulated via the sciatic nerve with the supramaximal voltage and the frequencies which were varied from 5 to 125 Hz. Table 10 presents the force developments of the soleus muscles in relation to the frequency of 4 groups. The average force was represented as the normalized tetanic tension (g/g tissue). The tetanic tension of soleus muscle developed in proportion to an increment in frequency of stimulation, and approached the maximum at frequency of 75 Hz. Then, it tended to reach a plateau as the

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Table 8 Mean time to peak tensions of isometric twitch of the soleus muscles of 4 experimental groups (n= 8 each).

Group	Mean time to peak tension (ms)
I	27.5 ± 0.7
II	33.9 ± 1.9*
III	29.2 ± 1.9
IV	30.0 ± 0.7

* $P < 0.05$ between groups I and II

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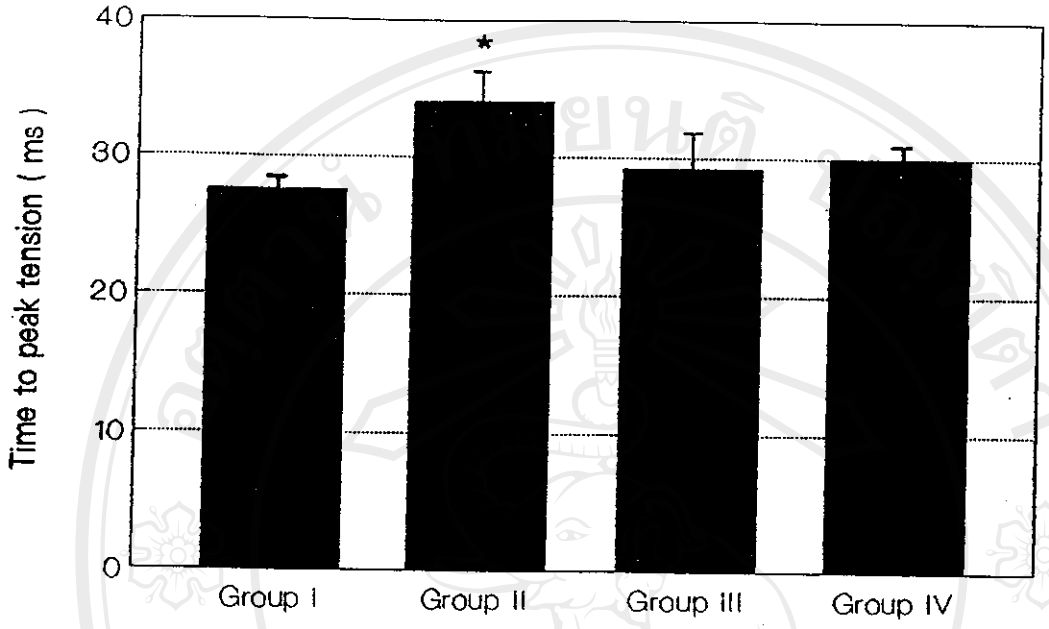

Figure 12 Comparison of time to peak tensions of isometric twitch of soleus muscles among 4 experimental groups.

* $P < 0.05$ between group I and II

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Table 9 Mean one-half relaxation times of isometric twitch of the soleus muscles of 4 experimental groups (n = 8 each).

Group	Mean one-half relaxation time (ms)
I	21.7 ± 1.0
II	38.1 ± 4.4*
III	28.1 ± 1.0*
IV	28.2 ± 1.0

* $P < 0.05$ between groups I and II,I and III

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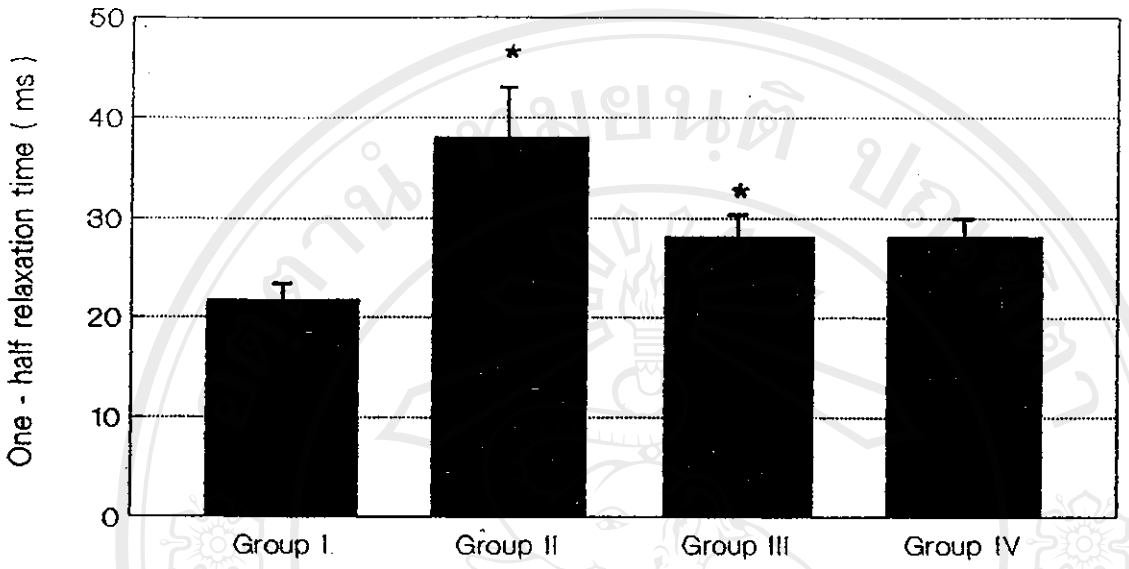

Figure 13 Comparison of one - half relaxation times of isometric twitch of soleus muscles among 4 experimental groups.

* $P < 0.05$ between groups I and II, I and III

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frequency was increased further (Figure 14). As a result of hypothyroidism, the normalized tetanic tensions of the soleus in group II at all frequencies (from 5 to 125 Hz) were depressed, and significant different ($P<0.05$) from those noted in group I. It was observed that the exercise training produced the marked increase in the development of tetanic tensions of the soleus. The significant increase ($P<0.05$) in the normalized tetanic tension of soleus in group III was found when compared with those observed in group I at all frequencies (between 5 - 125 Hz). In addition, there was a significant difference ($P<0.05$) in the normalized tetanic tensions of soleus between groups III and IV at all frequencies, except at frequencies 15 Hz. When compared with the data obtained from group II, the normalized tetanic tension of the soleus in group IV was significantly increased ($P<0.05$) at all frequencies.

Figure 15 illustrates the examples of the isometric tetanic tensions during the fatigue stimulation paradigm from control, hypothyroid, exercise and hypothyroid - exercise soleus muscles. The decrease of isometric tetanic tension of soleus was observed during the 2 minutes period of repetitive stimulation. In order to assess the muscle endurance property, the reduction in isometric tetanic tension during repetitive stimulation was qualified by the " Fatigue index " : ratio of isometric tetanic tension at the end of 2 minutes to initial tension. As shown in Table 11, the means of fatigue indexes were 0.66 ± 0.05 and 0.40 ± 0.04 for the soleus muscles in groups I and II, respectively and there was a significant difference ($P<0.05$) from each other. The fatigue index of the soleus in group III was 0.82 ± 0.02, being significantly greater ($P<0.05$) than those obtained from groups III and IV (0.40 ± 0.04 and 0.55 ± 0.06). Likewise, the significant difference ($P<0.05$) in the mean fatigue index of the soleus was noted between groups II

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Table 10 Force - frequency relationships of soleus muscles of 4 experimental groups (n = 8 each).

Frequency (Hz)	Mean normalized tetanic tension (g / g tissue)			
	Group I	Group II	Group III	Group IV
5	349.6 ±11.4	298.9 ± 13.3*	417.0 ± 13.6*	360.7 ± 15.1**,+
10	429.4 ± 9.6	362.4 ± 14.6*	489.5 ± 11.2*	435.6 ± 14.3**,+
15	489.0 ±15.3	406.8 ± 12.3*	504.6 ±17.7*	492.3 ±16.0**
20	648.8 ±13.0	510.0 ± 20.2*	656.2 ±16.4*	588.7 ±16.5**,+
30	749.3 ±13.0	667.5 ±16.8*	908.6 ±20.3*	776.5±17.6**,+
40	863.3 ±15.2	752.4 ±21.7*	990.1±17.0*	841.9±17.2**,+
50	891.0 ±19.4	773.7 ±18.3*	1008.1±18.6*	871.8±19.0**,+
75	985.0 ±18.7	832.4 ± 20.9*	1089.2±16.4*	949.3±22.3**,+
100	998.8 ±20.3	867.7 ±19.7*	1096.1±15.5*	947.7±15.8**,+
125	996.3 ±18.7	852.4 ±19.2*	1102.5±18.3*	956.7±19.7**,+

* $P < 0.05$ between groups I and II, I and III

** $P < 0.05$ between groups II and IV

\+ $P < 0.05$ between groups III and IV

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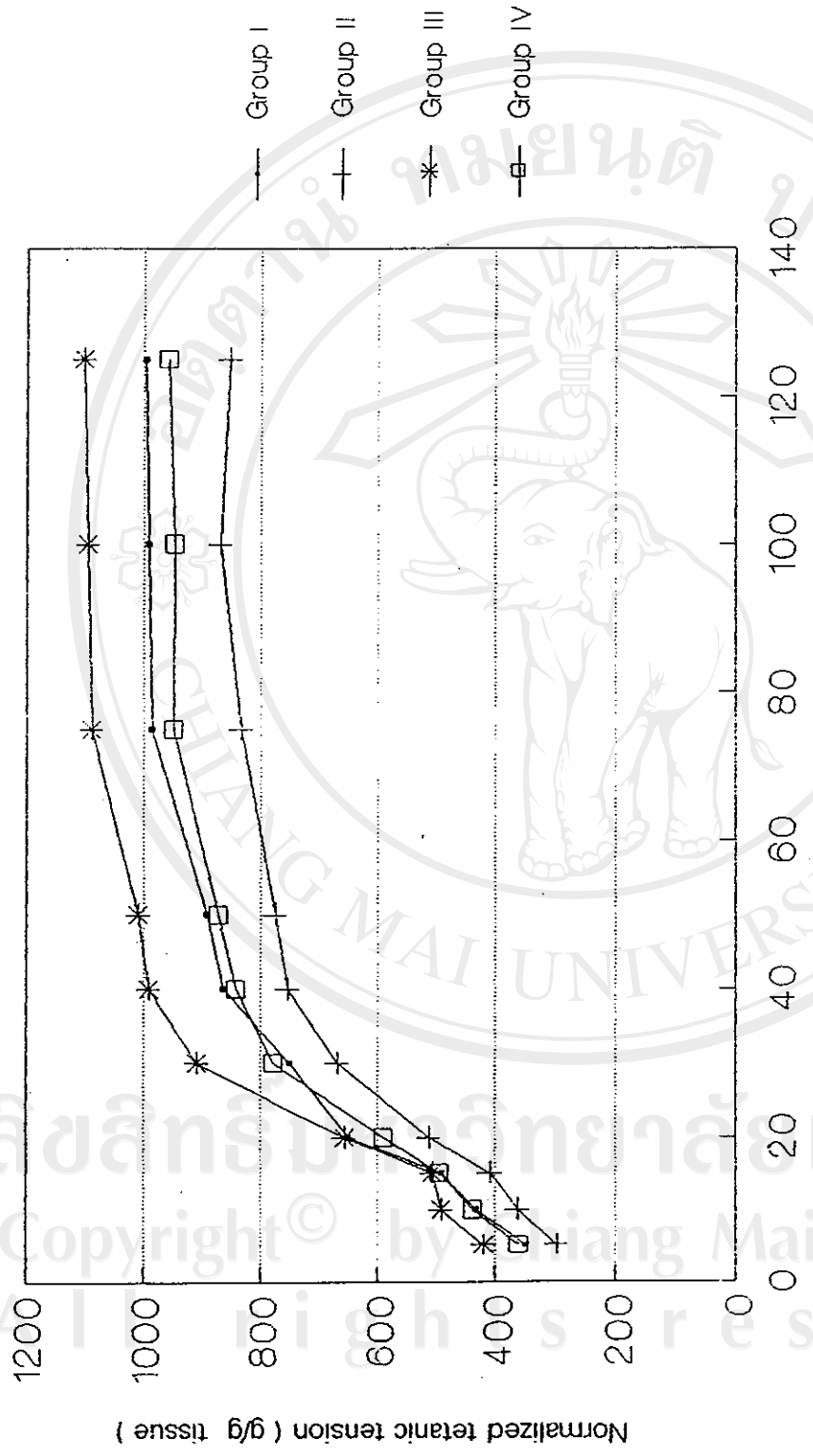

Figure 14 Comparison of force - frequency curves of soleus muscles among 4 experimental groups.

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and IV. The histograms in Figure 16 demostrate the comparison of the fatigue indexes of the soleus muscles among 4 groups.

Figure 17 illustrates the typical isometric twitches recorded from the control, hypothyroid, exercise and hypothyroid - exercise plantaris muscles. As presented in Table 12, the mean twitch tensions of the plantaris muscles, absolute or normalized twitch tensions, were 85.4±4.4 g or 226.6±11.2 g/g tissue in group I and 73.9±3.2 g or 224.2±12.4 g/g tissue in group II. It appeared that absolute twitch tension of plantaris in group II was about 13.5 % lower than the value observed in group I. However, when normalized twitch tensions were compared, the difference was not large enough to be statistically significant ($P > 0.05$). The twitch tensions of the plantaris muscles were 87.6±3.5 g or 242.8± 17.8 g/g tissue in group III and 76.6±5.5 g or 248.2±17.8 g/g tissue in group IV. The significant differences in both of absolute and normalized twitch tensions of plantaris muscles were not observed ($P>0.05$) between these two groups.
In group III, the absolute or normalized twitch tension of plantaris exhibited an insignificant difference ($P>0.05$) from the value noted in group I. Likewise, no significant difference ($P>0.05$) in the absolute or normalized twitch tension of the plantaris was observed between groups II and IV. The comparison of normalized twitch tensions of plantaris muscles among 4 experimental groups are depicted in Figure 18.

Table 13 and the histograms in Figure 19 illustrate the mean time to peak tensions (TPTs) of isometric twitches of plantaris muscles of 4 groups. The TPTs of isometric twitches of plantaris muscles were 21.9±0.9 and 24.8±1.2 ms in groups I and II, respectively. The TPT of isometric twitch of plantaris in group II seemed to prolong but no significant difference was found ($P>0.05$) between

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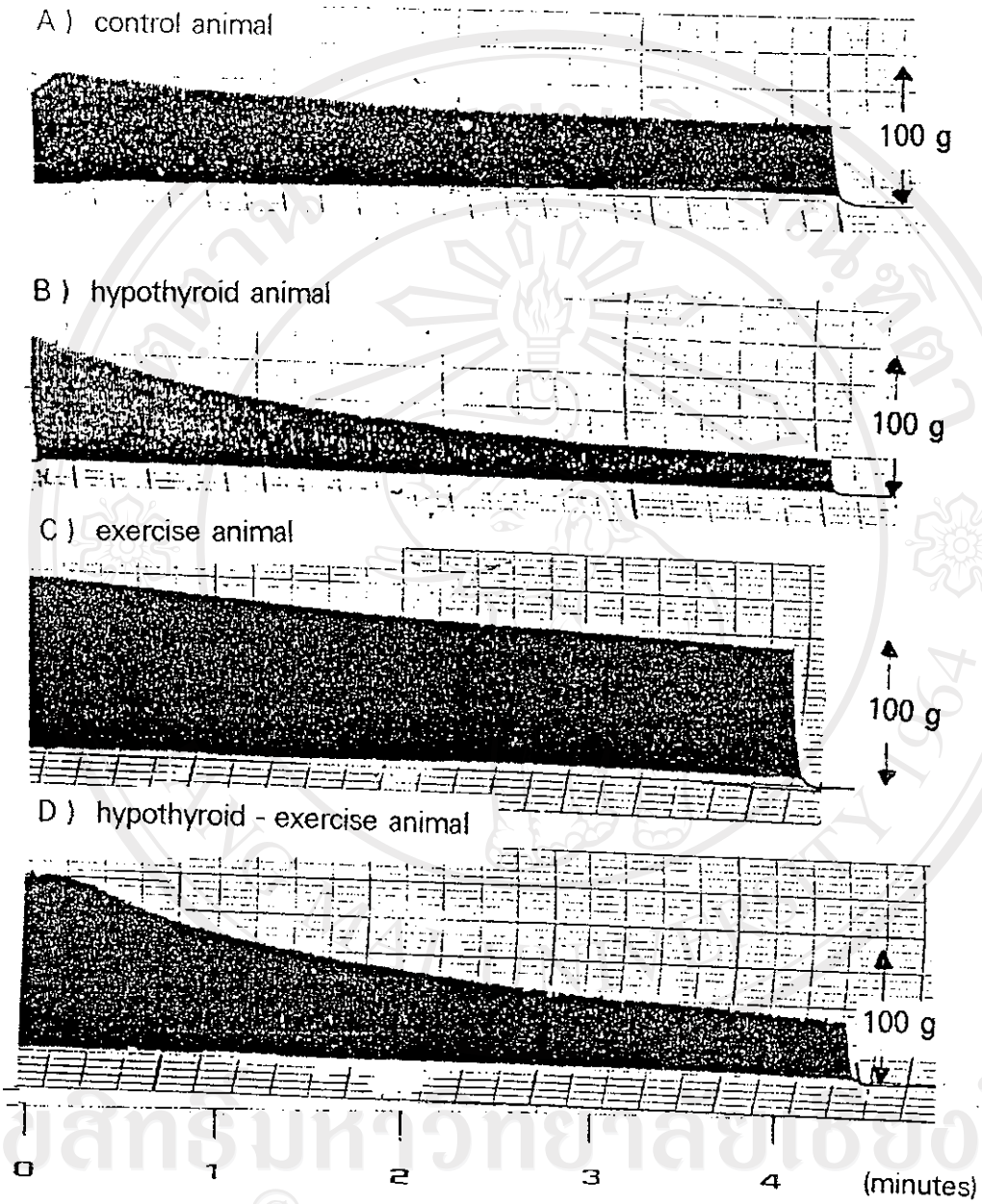

Figure 15. Examples of isometric tetanic tensions during repetitive stimulation for 2 minutes from control (A), hypothyroid (B), exercise (C) and hypothyroid - exercise (D) soleus muscles.

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Table 11 Mean fatigue indexes of soleus muscles of 4 experimental groups (n = 8 each).

Group	Mean fatigue index
I	0.66 ± 0.05
II	0.40 ± 0.04*
III	0.82 ± 0.02*
IV	0.55 ± 0.06**,+

* P < 0.05 between groups I and II,I and III

** P < 0.05 between groups II and IV

\+ P < 0.05 between groups III and IV

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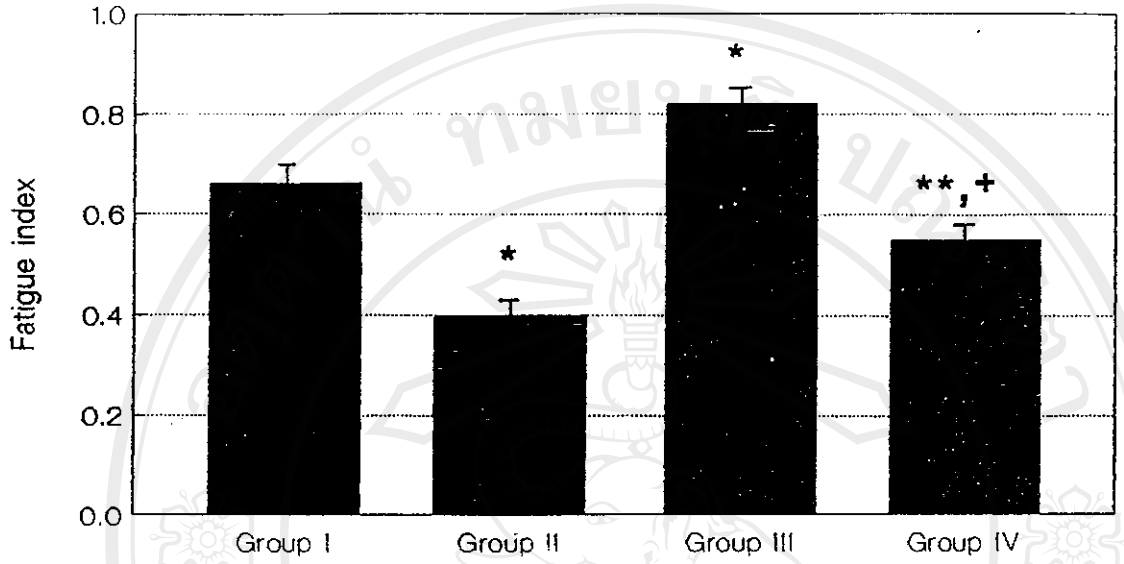

Figure 16 Comparison of fatigue indexes of soleus muscles among 4 experimental groups.

*P < 0.05 between group I and II, I and III

**P < 0.05 between group II and IV

+P < 0.05 between group III and IV

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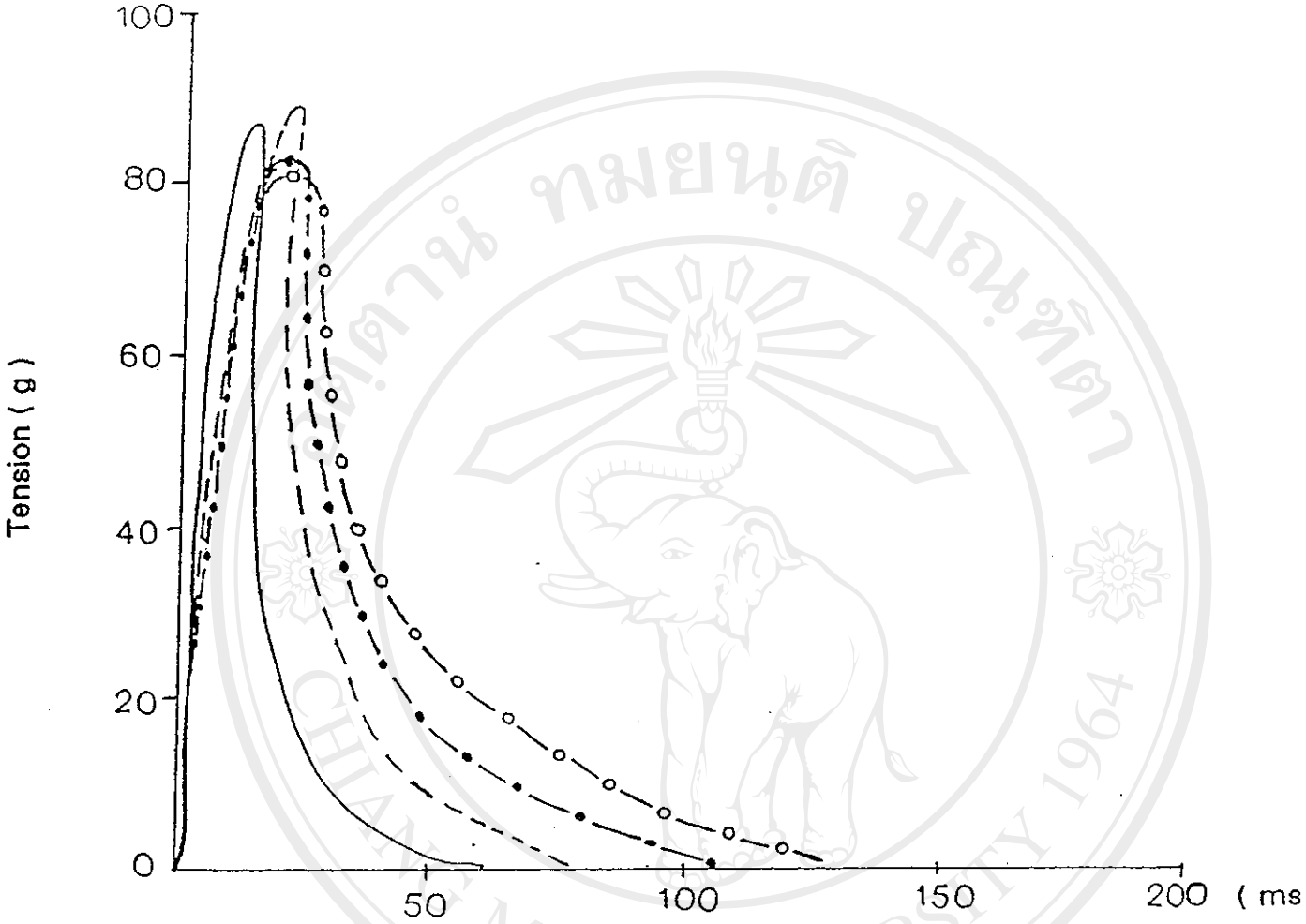

Figure 17 Typical examples of isometric twitches from control (———), hypothyroid (—— o ——), exercise (– – – –) and hypothyroid - exercise (—— • ——) plantaris muscles.

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Table 12 Mean isometric twitch tensions of the plantaris muscles of 4 experimental groups (n= 8 each).

Group	Mean absolute twitch tension (g)	Mean normalized twitch tension (g / g tissue)
I	85.4 ± 4.4	226.6 ± 11.2
II	73.9 ± 3.2	224.2 ± 12.4
III	87.6 ± 3.5	242.8 ± 17.8
IV	76.6 ± 5.5	248.2 ± 17.8

$P > 0.05$

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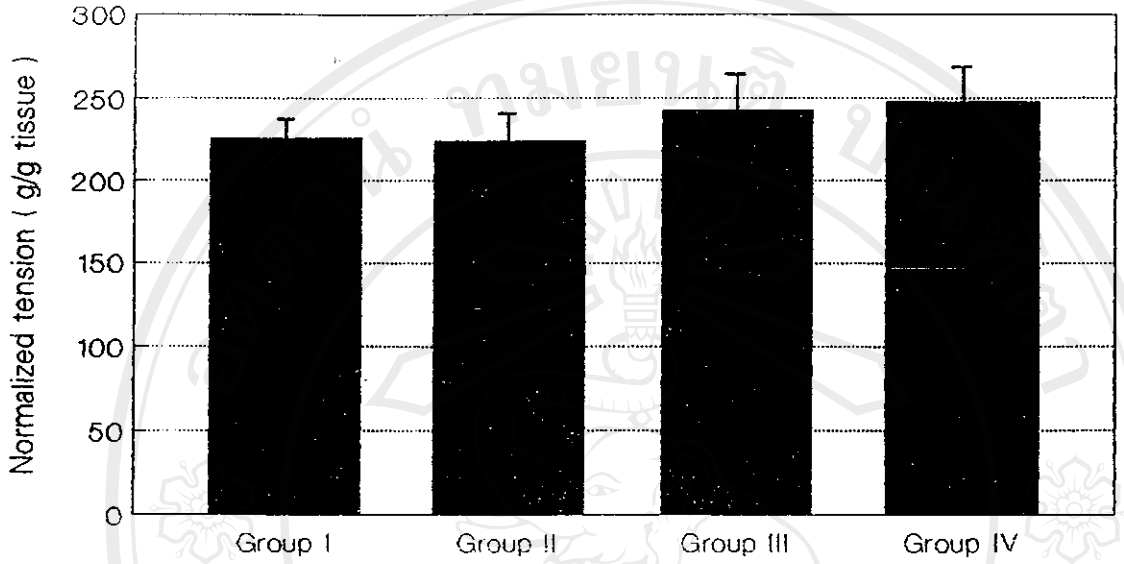

Figure 18 Comparison of isometric twitch tensions of plantaris muscles among 4 experimental groups.

$P > 0.05$

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Table 13 Mean time to peak tensions of isometric twitch of the plantaris muscles of 4 experimental groups (n = 8 each).

Group	Mean time to peak tension (ms)
I	21.9 ± 0.9
II	24.8 ± 1.2
III	23.0 ± 1.0
IV	24.9 ± 1.2

$P > 0.05$

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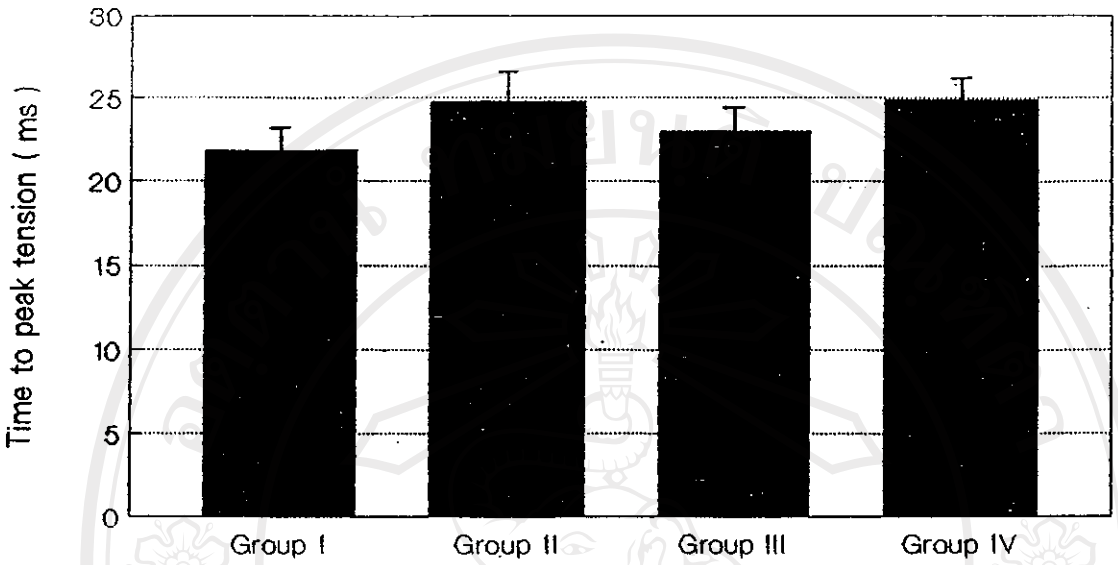

Figure 19 Comparison of time to peak tensions of isometric twitch of plantaris muscles among 4 experimental groups.

$P > 0.05$

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groups I and II. The TPTs of isometric twitch of plantaris muscles in group III (23.0±1.0 ms) appeared to be increased. However, when compared with the result obtained from group I, the difference was not large enough to be statistically difference ($P>0.05$). In group IV, the TPT of isometric twitch of plantaris (24.9±1.2 ms) was almost identical to that observed in groups II and III.

It seemed likely that, a significant increase ($P<0.05$) in 1/2 RT of isometric twitch of the plantaris was observed in group II (19.1±0.6 ms) as compared with the control value in group I (13.9±0.6 ms) (Table 14). In group III, the 1/2 RT of isometric twitch of the plantaris (18.2±1.1 ms) was prolonged, and significant difference ($P<0.05$) from that noted in group I. The 1/2 RT of isometric twitch of the plantaris in group IV (18.6±0.9 ms) was equal to that observed in group III. When compared with group II, the 1/2 RT of isometric twitch of the plantaris in group IV was not significantly different ($P>0.05$). Figure 20 represents the comparison of mean 1/2 RT of isometric twitches of the plantaris muscles among 4 experimental groups.

The force - frequency relationship of plantaris muscle was also evaluated. The normalized tetanic tensions (g/g tissue) at each frequency of plantaris muscle of 4 experimental groups are illustrated in Table 15 and the comparison of force - frequency curves of plantaris muscle is graphically depicted in Figure 21. It was noted that the normalized tetanic tensions of plantaris muscles in 4 experimental groups appreciably developed in proportion to an increment in frequency of stimulation and reached the maximum at frequency about 100 Hz. The appreciable decrease in normalized tetanic tension of plantaris was observed in group II. The significant difference of the normalized tetanic tension was found between groups I and II at all frequencies except at frequency 5 Hz. As a result

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Table 14 Mean one-half relaxation times of isometric twitch of the plantaris muscles of 4 experimental groups (n = 8 each).

Group	Mean one-half relaxation time (ms)
I	13.9 ± 0.6
II	19.1 ± 0.6*
III	18.2 ± 1.1*
IV	18.6 ± 0.9

* $P < 0.05$ between groups I and II, I and III

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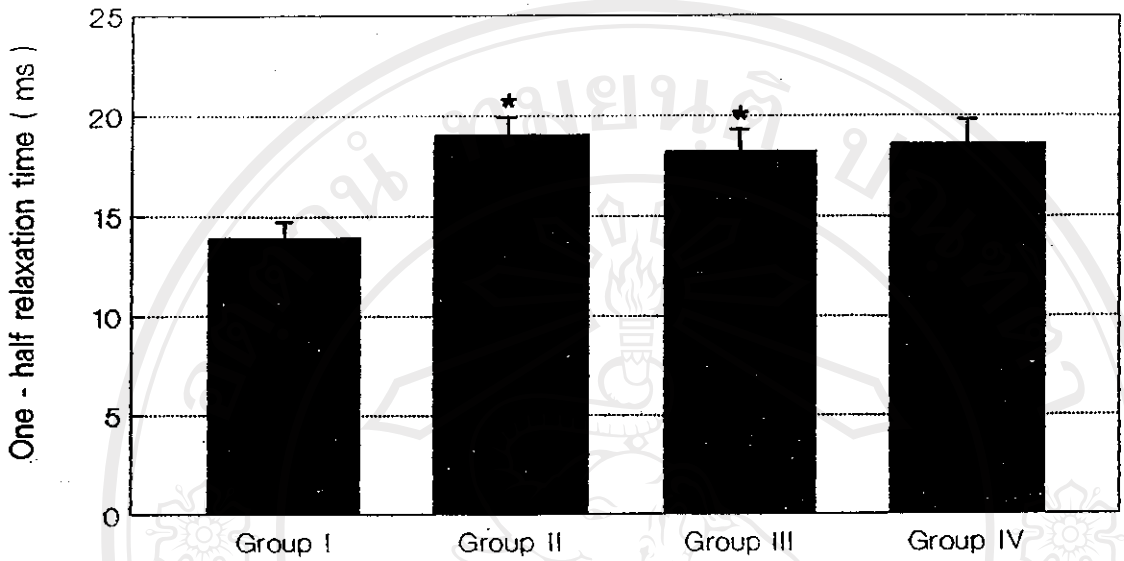

Figure 20 Comparison of one - half relaxation times of isometric twitch of plantaris muscles among 4 experimental groups.

* $P < 0.05$ between groups I and II, I and III

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Table 15 Force - frequency relationships of plantaris muscles of 4 experimental groups (n = 8 each).

Frequency (Hz)	Mean normalized tetanic tension (g / g tissue)			
	Group I	Group II	Group III	Group IV
5	385.5 ±12.9	330.6±22.1	394.6±17.5	390.3±19.2**
10	428.6 ± 17.4	357.8±19.6*	486.9±11.6*	435.9±18.4**,+
15	457.9 ±19.2	384.7±21.3*	541.1±19.3*	461.5±19.8**,+
20	489.3 ±23.2	406.6±22.0*	565.9±18.7*	504.0±21.2**,+
30	540.8 ±15.5	466.0±17.6*	649.8±17.5*	565.5±22.5**,+
40	649.7 ±20.3	535.8±23.6*	798.0±19.9*	704.2±24.1**,+
50	837.5±23.5	684.5±20.7*	931.2±23.2*	840.8±19.6**,+
75	1095.9±18.6	846.7±23.2*	1183.9±21.7*	1093.0±20.7**,+
100	1165.2±18.6	948.6±24.2*	1328.2±23.3*	1167.3±23.8**,+
125	1170.1±21.2	945.2±28.6*	1330.4±20.6*	1184.1±26.6**,+

* $P < 0.05$ between groups I and II, I and III

** $P < 0.05$ between groups II and IV

\+ $P < 0.05$ between groups III and IV

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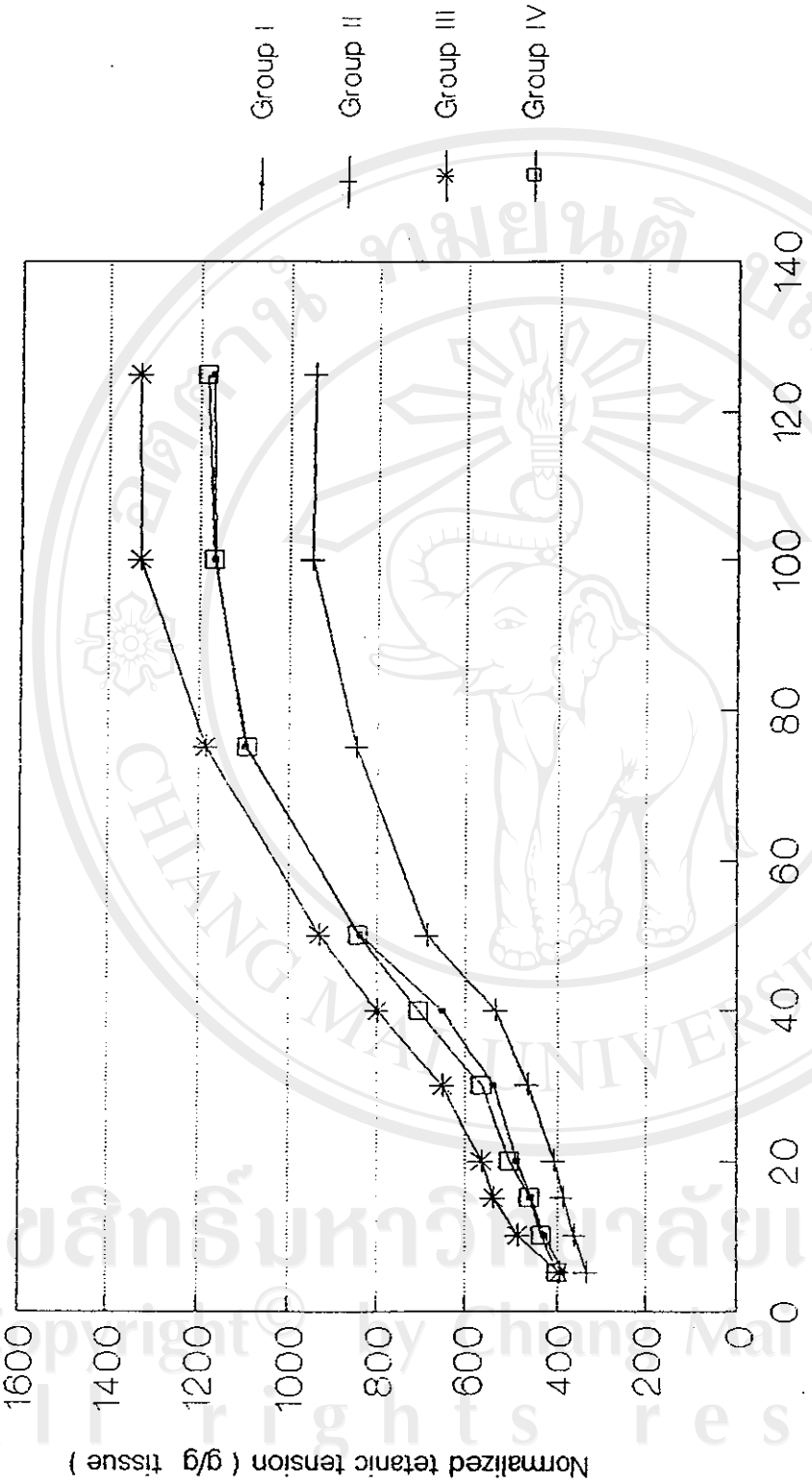

Figure 21 Comparison of force - frequency curves of plantaris muscle among 4 experimental groups.

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of exercise, the development of normalized tetanic tensions of plantaris muscle during the frequencies of 10 to 125 Hz in group III was significantly greater ($P < 0.05$) than those noted in group I. In group IV, there was less developed normalized tetanic tension of plantaris as compared with the data obtained from group III and the significant difference of normalized tetanic tensions at frequencies of 10 to 125 Hz was observed. However, when compared with the results observed in group II, the normalized tetanic tensions of plantaris at all frequencies (from 5 to 125 Hz) in group IV were found to be significantly increased ($P<0.05$).

The examples of isometric tetanic tensions from control, hypothyroid, exercise and hypothyroid - exercise plantaris muscles during the fatigue stimulation paradigm are shown in Figure 22. The endurance property of plantaris was estimated by the fatigue index which was calculated from the ratio of isometric tetanic tension at the end of 2 minutes to the initial tension. As shown in Table 16, the fatigue index in group II (0.23 ± 0.02) was significantly decreased ($P<0.05$) approximately 50% from that observed in group I (0.42 ± 0.03). The fatigue indexes of plantaris muscle were 0.54 ± 0.02 in group III, and 0.41 ± 0.03 in group IV and the significant difference ($P<0.05$) was also found. When compared with group I, the significant increase ($P<0.05$) of the fatigue index of plantaris in group III was noted. Likewise, there was also a significant difference in the fatigue indexes between groups II and IV. Figure 23 represents the comparison of mean fatigue indexes of the plantaris muscles among 4 experimental groups.

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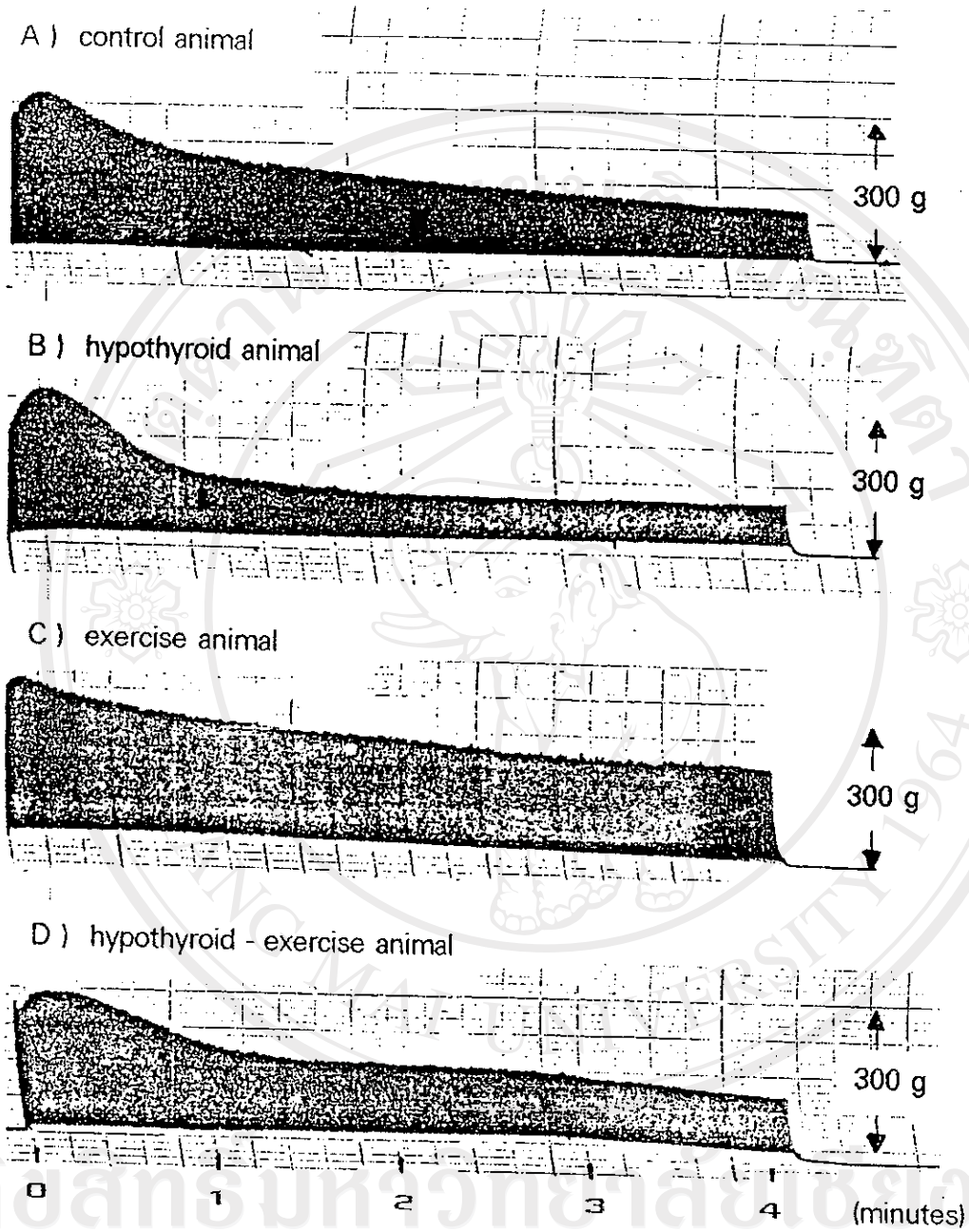

Figure 22 Examples of isometric tetanic tensions during repetitive stimulation for 2 minutes from control (A), hypothyroid (B), exercise (C) and hypothyroid - exercise (D) plantaris muscles.

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Table 16 Mean fatigue indexes of the plantaris muscles of 4 experimental groups (n = 8 each).

Group	Mean fatigue index
I	0.42 ± 0.03
II	0.23 ± 0.02*
III	0.54 ± 0.02*
IV	0.41 ± 0.03**,+

* P < 0.05 between groups I and II, I and III

** P < 0.05 between groups II and IV

+ P < 0.05 between groups III and IV

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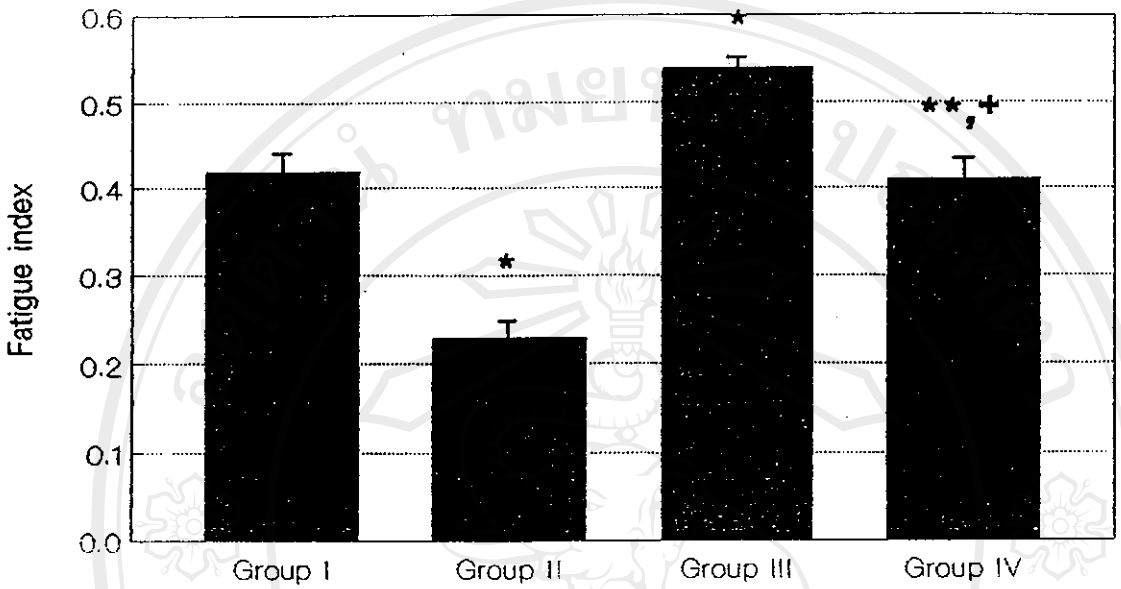

Figure 23 Comparison of fatigue indexes of plantaris muscles among 4 experimental groups.

*P < 0.05 between group I and II, I and III

**P < 0.05 between group II and IV

+P < 0.05 between group III and IV

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