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Publisher: Taylor & Francis

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International Journal of Occupational Safety and Ergonomics

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/tose20>

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Published online: 08 Jan 2015.

To cite this article: Akiko Yamashita, Mitsuyuki Kawakami, Yoshimasa Inagaki & Takao Ohkubo (2015) A Prescriptive Exercise Program for Health Maintenance, International Journal of Occupational Safety and Ergonomics, 7:2, 195-209

To link to this article: <http://dx.doi.org/10.1080/10803548.2015.11076486>

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A Prescriptive Exercise Program for Health Maintenance

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The aim of this study was to design a prescriptive exercise program for people of various age and fitness basing on the popular in Japan Radio Physical Fitness Exercise, a program based on an experimental approach. The evaluation indices used in the experiment were heart rate (HR), oxygen consumption, and electrical activity of the rectus femoris, latissimus dorsi, and trapezius muscles, which measured during various motion elements of the program performed at various rate. The results of this study enable to calculate equations for predicting HR during exercise from relative metabolic rate (RMR). The data on HR, RMR, and myoelectric potential presented in this study may be a basis for designing individual exercise programs for elderly people.

health maintenance prescriptive exercise program aging society
heart rate relative metabolic rate myoelectric potential

1. INTRODUCTION

In 1995, the National Institute of Population and Social Security Research reported that the average lifespan of the Japanese male was 76.36 years and that of the Japanese female 82.84 years. These data showed an extended life span by 1.41 years for men and by 2.09 years for woman in comparison with the 1985 statistics. If this tendency continues, in only 24 years Japan will become an aged society compared to Western countries. In Japan, the population of people aged 65 years or older will reach 25.2%. Therefore one of the important problems is and will continue to be the maintenance of personal health of aging people. As the length of life after retirement continues to increase, the lifestyle of the elderly living at home tends to limit their physical activity. Although a number of people exercise in sports clubs or local gymnasiums, poor accessibility and high cost limit the possibility of elderly people to actively participate in such programs. Therefore, an exercise program appropriate for various age groups, from the young to the advanced, needs to be prescribed and be accessible to the population as a whole. It is also well-known that random exercise done by older people without concern for their current state of health can be dangerous and can often have adverse effects (Cooper, 1963, 1970; Hettinger, Brikhead, Horvath, Issekutz, & Rodahl, 1961; Maeda & Usami, 1989; Robinson, 1938; Yamashita, Kawakami, Ukai, & Ohkubo, 1988). These issues show the need for not only a prescriptive exercise program but also for a formula for prescribing particular exercises for the elderly (Yamashita Kawakami, Inagaki, Ukai, & Ohkubo, 1997). This paper presents a proposal for designing an exercise program for health maintenance based on the motion elements of the Japanese Radio Physical Fitness Exercise. The results also provide a formula for calculating the effects of exercises so that effective yet safe exercises can be prescribed.

2. METHOD

The Radio Physical Fitness Exercise (13 postures) was chosen as the subject of study because it is well-known and one of the most popular fitness exercise programs in Japan. The research method included an analysis of the structural content, intensity, and kind of motion elements in the Fitness Program (Table 1 and Figure 1). The influence of exercises on the physiological functions was determined and indices used in the experiment were

obtained by measuring heart rate (HR), integrated electromyograms registered at 5-s intervals (later referred to as myoelectric potential), and oxygen intake.

TABLE 1. Motion Elements of Radio Physical Fitness Exercise

Motion Element	Engaged Parts of Body	Engaged Joints
①	arms, shoulders, legs	shoulders, ankles
② ⑫	arms, shoulders, knees	shoulders, elbows, knees, ankles
③	arms, shoulders, chest	shoulders
④	arms, shoulders	shoulders, elbows
⑤	arms, shoulders, back, sides, loins	shoulders
⑥	back, loins	—
⑦	arms, shoulders, back, loins	—
⑧	arms, shoulders, legs	shoulders, elbows, ankles
⑨	shoulders, back, chest, loins	shoulders
⑩	back, loins	shoulders
⑪	arms, shoulders, legs	shoulders, loins, ankles
⑬	arms, shoulders	shoulders

The participants were 21 healthy women (ranging in age from 31 to 58 years) who participated in Experiments I and II. The data were taken over a period of 2 months. In Experiment III the participants were 11 healthy males (ages 21 to 25 years), and data were collected over a period of 1 month. Both groups were familiar with the basic exercise program and all tests were done in a controlled environment at a temperature of 26 °C and a humidity of 60%.

The measurements of heart rate, myoelectric potential, and metabolic rate were taken with 4-channel memory equipment produced by VINE Co., Japan.

The study was composed of three experiments. In Experiment I relative metabolic rate (RMR) and heart rate (HR_{submax}) of participants were measured during each of the 13 postures of the program (see Table 1 and Figure 1). Experiment II was designed to provide data on the differences in RMR and HR related to the rate (Conditions A, B, C) of each motion element. In Experiment III RMR was measured through exercises performed with the use of the upper or lower half of the body. By developing a formula for the upper and lower half of the body and the whole body, prescriptive exercises could be developed for each person depending on his or her exercise ability. The experimental conditions for Experiment I, II, and III are shown in Table 2 and the gauging points for measuring the myoelectric potential are

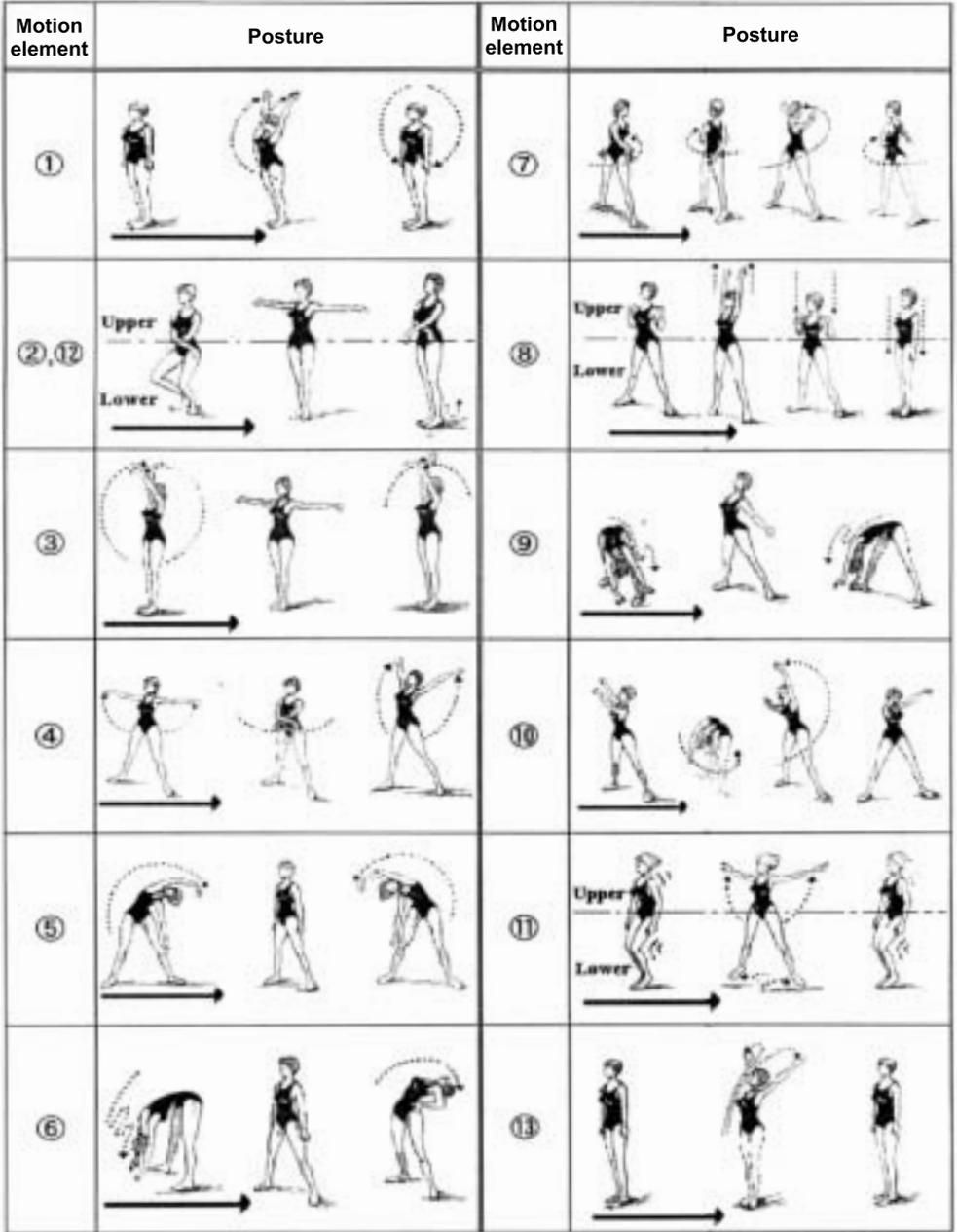


Figure 1. Posture of each motion element.

shown in Figure 2. RMR was calculated by using formula 1 (Ohshima & Ohkubo, 1993):

$$RMR = \frac{\text{Working metabolism}}{\text{Resting metabolism}} \quad (1)$$

TABLE 2. Contents of Experiment

<p>Motions and motion speed</p>	<p>Experiment I: Single motion elements presented in Table 1. Experiment II: Series of motion elements presented in Table 1. Condition A (Average 58 repetitions/min) Motion elements ①, ②, ③, ④, ⑤, ⑥, ⑦, ⑧, ⑩, ⑫, ⑬ are 60 repetitions/min, ⑨ is 52 repetitions/min, and ⑪ is 96 repetitions/min. Condition B (Average 76 repetitions/min) Motion elements ①, ②, ③, ④, ⑤, ⑥, ⑦, ⑧, ⑫, ⑬ are 80 repetitions/min, ⑨ is 66 repetitions/min, ⑩, is 72 repetitions/min, and ⑪, is 126 repetitions/min. Condition C (Average 96 repetition/min) Motion elements ①, ②, ③, ④, ⑤, ⑥, ⑦, ⑧, ⑫, ⑬ are 96 repetitions/min, ⑨ is 84 repetitions/min, ⑩, is 88 repetitions/min, and ⑪, is 160 repetitions/min. Experiment III: Each part of the motion elements presented in Table 1. M1: motion element ⑧. M2: only the motion of the upper half of the body on ⑧. M3: only the motion of the lower half of the body on ⑧. M4: motion element ⑪. M5: only the motion of the upper half of the body on ⑪. M6: only the motion of the lower half of the body on ⑪. M7: motion element ②. M8: only the motion of the upper half of the body on ②. M9: only the motion of the lower half of the body on ②. M1, M2, M3: 80 repetitions/min. M4, M5, M6: 126 repetitions/min. M7, M8, M9: 80 repetitions/min.</p>
<p>Evaluated indices</p>	<p>Evaluated indices are change of oxygen intake, functions of the heart and lungs (HR averaged for 5-s intervals), and muscle function (myoelectric potentials of surface electrodes [vitrode-S] were placed in pairs with 30-mm center distance upon carefully prepared skin covering the muscles studied, which were trapezius, latissimus dorsi, and rectus femoris muscle).</p>
<p>Participants</p>	<p>Experiment I and Experiment II: 21 healthy women randomly selected. Age: 31–58 years (Average 46.6 years ± 8.7) Height: 143–159 cm (Average 153.3 cm ± 4.6). Weight: 41–72 kg (Average 53.0 kg ± 7.6). Experiment: 11 healthy men randomly selected. Age: 21–25 years (Average 22.5 years ± 1.4) Height: 163–172 cm (Average 168.2 cm ± 3.1). Weight: 58–72 kg (Average 65.5 kg ± 4.4).</p>
<p>Other conditions</p>	<p>The experiments were performed inside a room (average temperature: 26 °C, average humidity: 60%). Participants were well practiced in the experimental motions.</p>

Notes. ① ... ⑬—cf. Table 1 and Figure 1.

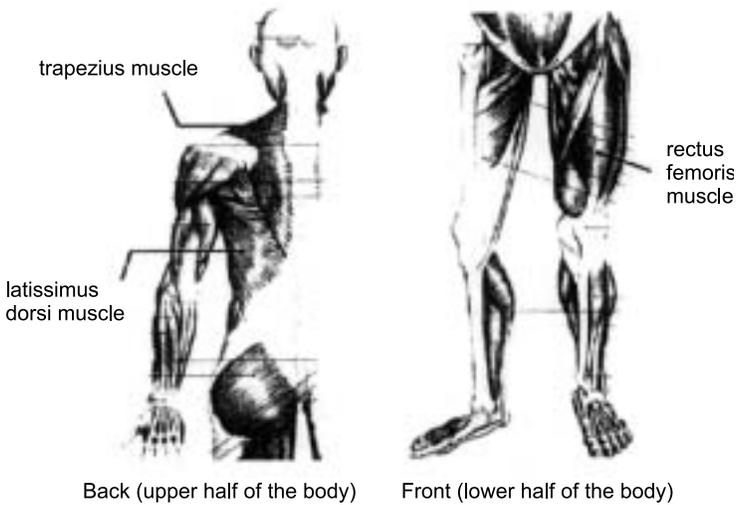


Figure 2. Gauging points of myoelectric potential.

3. RESULTS AND DISCUSSION

3.1. Experiment I and II

Figure 3 shows the results of RMR calculated from oxygen intake. It is clear that the RMRs of ②, ⑪ and ⑫ motion elements, which engage the lower half of the body, are relatively large. Generally, RMR increases with motion speed, except for motion element ⑪, that is, high jumping when RMR is the largest during condition A. An analysis of variance showed that RMR is significantly influenced by the mode of exercise and its speed

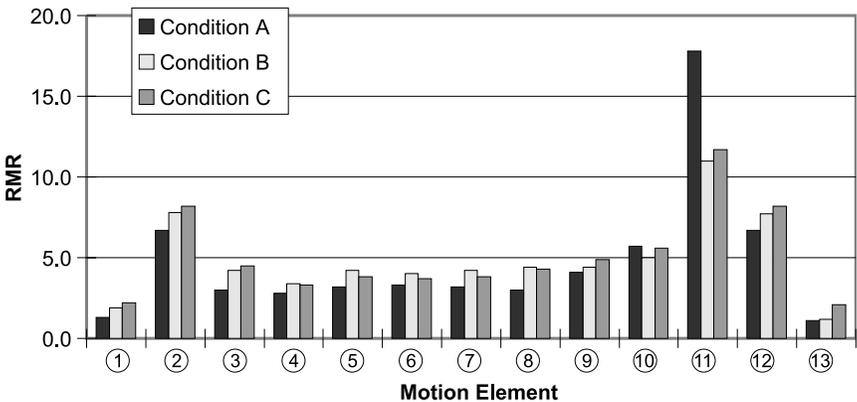


Figure 3. Relative metabolic rate (RMR) on each motion element.

($p < .01$). Moreover, the contribution of the motion element to the total RMR variability is 71.5%. Therefore, the motion element composition is an important factor of exercise intensity.

Figure 4 shows the results of the submaximal heart rate (HR_{submax}) measurement during a stationary state for each motion element. As the pattern of HR_{submax} was similar to that of RMR, it is concluded that HR can be used for the evaluation of exercise intensity.

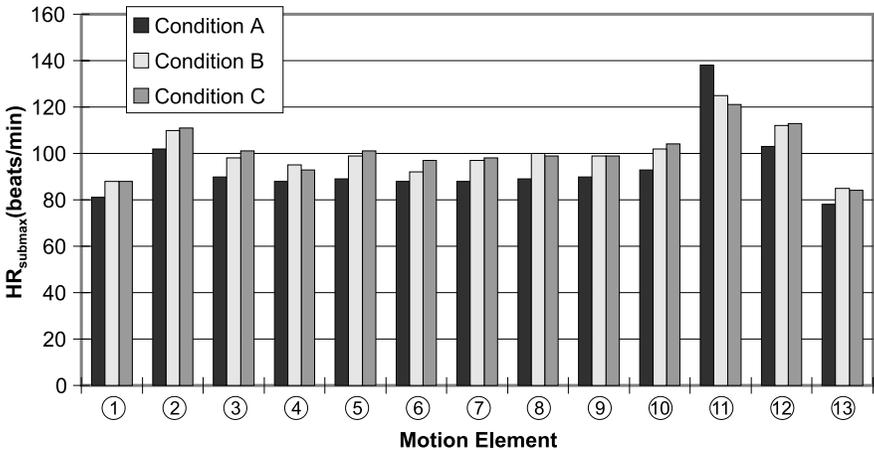


Figure 4. Heart rate (HR_{submax}) on each motion element.

The analysis of variance showed a significant influence ($p < .01$) of motion speed on myoelectric potential. The contribution of speed to the total variability was 42.2% in the trapezius muscle, 17.7% in latissimus dorsi, and 45.0% in the rectus femoris muscle. These results are based on the intensity (RMR) of motion elements ②, ⑪ and ⑫. Therefore these motion elements may induce functional muscle improvement (Yamashita, Kawakami, Echizenya, & Ukai, 1995).

The results of RMR calculated from oxygen intake at each condition are presented in Figure 5. As can be seen, RMR increases with motion speed. The participants performed the Radio Physical Fitness Exercise under condition B every day for 2 months in order to estimate the training effect. As it is shown in Figure 6, the resting metabolism increased progressively with training time. A two-way (training time and participants) analysis of variance (ANOVA) showed a significant effect of the training on the resting oxygen consumption ($p < .01$). Moreover, a significant difference was found between the resting metabolic rate before and after 2 months of training ($p < .01$). The results confirmed those of Hori (1991), showing high

metabolic rates in trained participants. The results of Yamashita et al. (1995) showed the Radio Physical Fitness Exercise under condition B to be intensive enough to improve the functions of the heart and lungs even for elderly people.

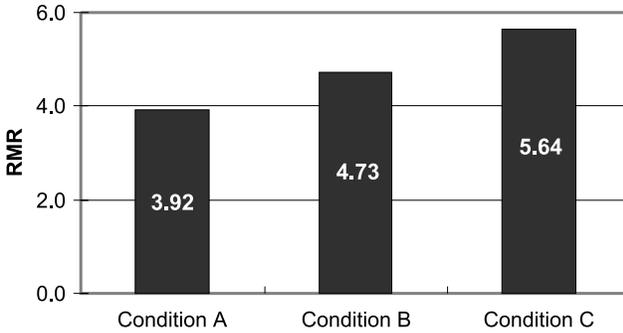


Figure 5. Relative metabolic rate (RMR) of Radio Physical Fitness Exercise performed at various rates.

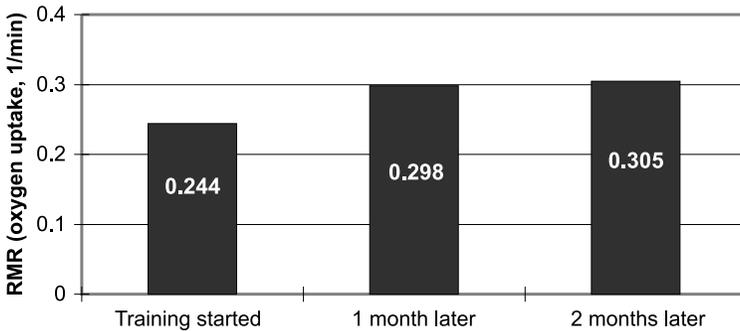


Figure 6. Effect of training on resting metabolic rate.

3.2. Experiment III

Table 3 presents a comparison of myoelectric potential of the rectus femoris muscle between motion elements. By using a t test significant differences ($p < .05$) were found between the motion of the whole body and the motion of the lower half of the body except for motion element ①. It appeared that the motion of the upper half of the body, (motion elements ② and ⑧) has a large effect on the myoelectric potential of the rectus femoris muscle.

The results of HR_{submax} in Experiment III are presented in Figure 7. As can be seen, the HR_{submax} was lowest during the motion of the upper half of the body, and highest during exercises engaging the whole body musculature

TABLE 3. t Test (Myoelectric Potential of Rectus Femoris Muscle)

Motion	φ	t_0 Value	Test
M1 \times M2	8	3.89**	reject
M1 \times M3	8	2.75*	reject
M2 \times M3	8	3.85**	reject
M4 \times M5	8	4.97**	reject
M4 \times M6	8	0.44	accept
M5 \times M6	8	4.48**	reject
M7 \times M8	7	2.66*	reject
M7 \times M9	7	3.65**	reject
M8 \times M9	7	2.97**	reject

Notes. **—difference at a 1% significant level, *—difference at a 5% significant level, φ —degree of freedom, M1 ... M9—cf. Table 2.

except for motion element ⑧. Table 4 summarizes the results of a three-way ANOVA (A: elements of exercise, B: kinds of exercises, C: participants) performed in order to detect factors that influence HR_{submax} . The data showed that HR_{submax} depended on each factor. Specifically, the contribution of the elements of the exercises was 29.3%, and that of the kinds of exercises was 29.5%.

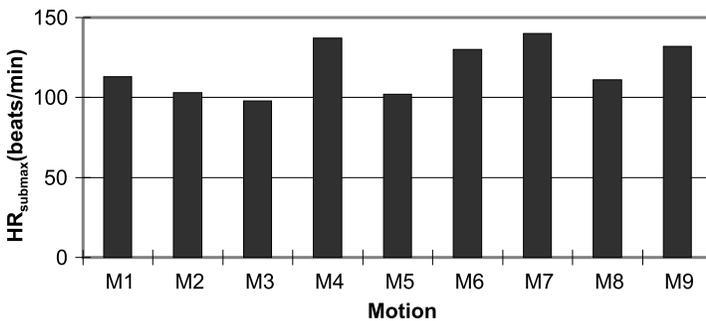
**Figure 7. Heart rate (HR_{submax}) on each motion (Experiment III).**

Figure 8 shows the results of RMR in Experiment III. As can be seen, RMR was increasing with an increase of the muscle engaged. It was lowest during the motion of the upper half of the body, and greatest during exercises engaging the whole body musculature. Table 5 shows a comparison of RMR during whole body exercises and the value obtained by adding RMR during upper and lower half of the body exercises. As it is shown, significant differences were found during motion elements ② and ⑧. Considering RMR as energy expended during 1 min (Asahino, 1981), the motion of the

TABLE 4. Three-Way ANOVA (HR_{submax})

Factor	SS	φ	V	F_0 value	ρ
A	6969	2	3684.0		29.3
B	7016	2	3508.0	175.3**	29.5
C	3894	8	486.8	176.5**	15.8
A × B	3052	4	763.0	24.5**	12.6
A × C	1152	16	72.0	38.4**	3.5
B × C	930	16	58.1	3.6**	2.6
e	636	32	19.9	2.9**	6.7
T	23648	80			100.0

Notes. **—difference at a 1% significant level, HR_{submax}—heart rate, φ —degree of freedom, V—variance, ρ —contribution rate, A—elements of exercise, B—kinds of exercises, C—participants.

whole body is smoother than individual motions of ② and ⑧. So, in order to show the relation of RMR during whole body exercise (RMR_w), upper half body exercise (RMR_U), and lower half body exercise (RMR_L), the following formula was suggested:

$$\text{RMR}_w = \alpha \times (\text{RMR}_U + \text{RMR}_L). \quad (2)$$

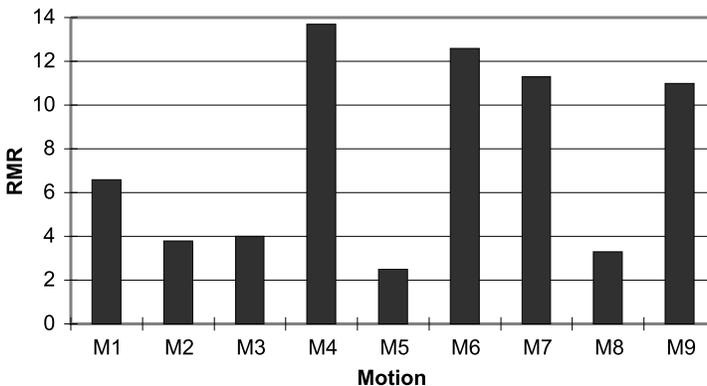


Figure 8. Relative metabolic rate (RMR) on each motion (Experiment III).

Coefficients α , obtained by the least squares method, are shown in Table 6. The following results can be seen from Table 6 and Table 3 (myoelectric potential of rectus femoris muscle): During motion elements ② and ⑧, exercise engaging the upper half of the body markedly affects the myoelectric potential of the rectus femoris muscle, subsequently, the value of α becomes low. On the other hand, during motion element ① its effect is less pronounced and α becomes larger.

TABLE 5. *t* Test (Relative Metabolic Rate [RMR] of the Whole Body and a Value That Added 2 RMRs)

Motion Element	ϕ	t_0 Value	Test
⑧	9	4.26**	reject
⑪	8	1.97	accept
②	6	4.03**	reject

Notes. **—difference at a 1% significant level, ϕ —degree of freedom, ⑧, ⑪, ②—cf. Table 1 and Figure 1.

TABLE 6. Comparison of Table 3 and α Calculated From Each Data

Motion Element	Coefficient α	<i>t</i> Test from Table 3
②	.79	3.65**
⑧	.86	2.75*
⑪	.92	0.44

Notes. **—difference at a 1% significant level, *—difference at a 5% significant level, ②, ⑧, ⑪—cf. Table 1 and Figure 1.

Regression lines 3, 4, and 5 of Figures 9, 10, and 11 were calculated in order to show the relation between RMR and HR_{submax} on each part of the exercise:

$$HR_{submax} \text{ (whole body)} = 78.15 + 4.67 \times RMR, \tag{3}$$

$$HR_{submax} \text{ (upper half of the body)} = 78.09 + 8.29 \times RMR, \tag{4}$$

$$HR_{submax} \text{ (lower half of the body)} = 76.38 + 4.60 \times RMR. \tag{5}$$

According to Karvonen, Kentla, and Mustal (1957), target heart rate (THR) can be calculated from formula 6 using α (changing the coefficient for physical capacity), HR_{max} , and HR_{rest} :

$$THR = HR_{rest} + \alpha \times (HR_{max} - HR_{rest}). \tag{6}$$

HR_{max} is given by formula 7 (Kattus, 1972):

$$HR_{max} = (220 - \text{age}). \tag{7}$$

Formula 8 can be calculated by inserting formula 7 into formula 6:

$$THR = (1 - \alpha) \times HR_{rest} + a \times (220 - \text{age}). \tag{8}$$

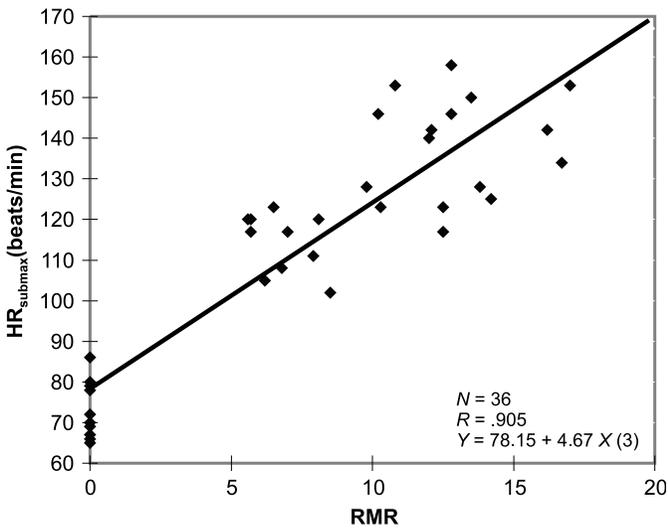


Figure 9. Relation between relative metabolic rate (RMR) and heart rate (HR_{submax} , whole body).

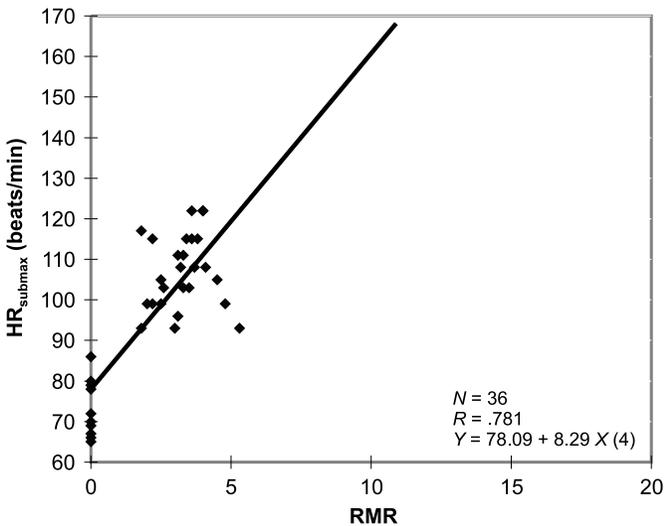


Figure 10. Relation between relative metabolic rate (RMR) and heart rate (HR_{submax} , upper half of the body).

Therefore, by substituting average HR_{rest} (72.9 beats/min) and average age (22.5 years old) of the participants into formula 8, the resulting THR_s are 135.2 beats/min ($\alpha = .5$), 147.7 beats/min ($\alpha = .6$) and 160.2 beats/min ($\alpha = .7$), respectively. Table 7 is RMR and a 2σ confidence for THR for each part of the exercises. At first sight, it was thought that exercises of the upper half of the body were suitable for the improvement of the functions of the heart and lungs. The upper limit of HR_{submax} is about 120 beats/min

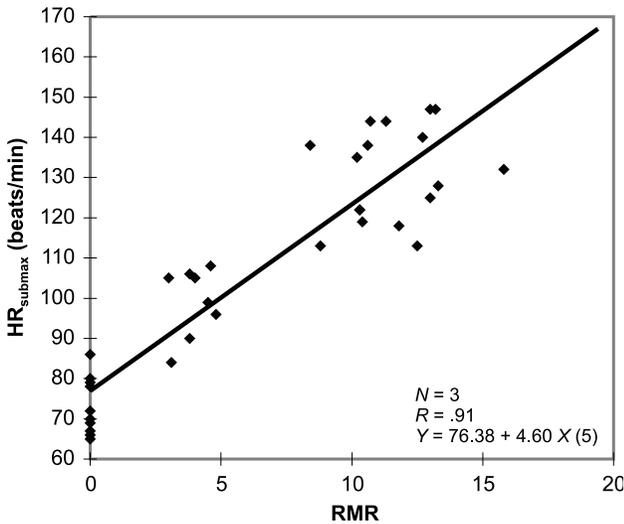


Figure 11. Relation between relative metabolic rate (RMR) and heart rate (HR_{submax} , lower half of the body).

for the upper half of the body only. But 130 beats/min of HR_{submax} is needed for prescriptive exercise programs if the goal is to improve heart and lung functions in healthy participants (Yamashita et al., 1995).

TABLE 7. Relative Metabolic Rate (RMR) Corresponding to Each Target Heart Rate (THR)

Parts of Exercise	50% THR ($\alpha = .5$) 135.20 beats/min	60% THR ($\alpha = .6$) 147.70 beats/min	70% THR ($\alpha = .7$) 160.20 beats/min
Whole body	12.22 \pm 5.28 (6.94, 17.50)	14.89 \pm 5.28 (9.61, 20.17)	17.57 \pm 5.28 (12.29, 22.85)
Upper half of the body	6.89 \pm 2.52 (4.37, 9.41)	8.40 \pm 2.52 (5.88, 10.92)	9.90 \pm 2.52 (7.39, 12.42)
Lower half of the body	12.79 \pm 4.57 (8.22, 17.36)	15.50 \pm 4.47 (10.93, 20.07)	18.22 \pm 4.57 (13.65, 22.79)

4. CONCLUSIONS

The design factors for a prescriptive exercise program for health maintenance have been proposed and various exercise combinations, their intensity, and the kind of motion elements involved have been discussed. The results indicate that

1. for the functional improvement of muscles, the characteristics of the motion elements is of significant importance;
2. condition B (average of 76 repetitions per minute) was intensive enough for the enhancement of the resting metabolic rate;
3. the motion elements of the upper half of the body had a high effect on the myoelectric potential of the leg muscles (rectus femoris muscle);
4. primary factors affecting HR_{submax} were the kind of exercise and the rate of performance;
5. an experimental formula, which shows the relation between RMR and HR_{submax} for different motion elements of each exercise, has been proposed.

Though exercise programs and health maintenance are common topics when discussing the elderly, there are few studies that provide an objective way to prescribe or design a health maintenance program to fit the particular needs or health conditions of each person. This becomes more of an issue for the elderly, where health, health maintenance, and fitness are more crucial to their quality of life. Whereas this study has limitations, it was done as a step to providing a beginning for research in this particular field.

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