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นิพนธ์ต้นฉบับ (Original article)
สรีรวิทยาการออกกำลังกายและกีฬา (Sports and Exercise Physiology)

การตอบสนองของระบบเมตาบอลิสมระหว่างการออกกำลังกายซ้ำด้วยแรงต้าน แบบไฮโดรลิกชนิดสองทางในวัยต่าง ๆ

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาการใช้พลังงานระหว่างการออกกำลังกายซ้ำด้วยแรงต้านแบบไฮโดรลิกชนิดสองทางในวัยต่างๆ อาสาสมัครชายจำนวน 32 คน ซึ่งสามารถจำแนกได้ 4 กลุ่มตามอายุ ดังนี้ กลุ่ม 1 (18–24 ปี), กลุ่ม 2 (25–34 ปี), กลุ่ม 3 (35–49 ปี) และกลุ่ม 4 (50–59 ปี) โดยประเมินการใช้พลังงานจากการใช้ออกซิเจนและการสร้างคาร์บอนไดออกไซด์ระหว่างการออกกำลังกายทั้ง 5 เครื่อง ซึ่งทดสอบจากการออกกำลังกายที่มีการเพิ่มความหนักตั้งแต่ระดับ 1 ถึงระดับ 4 โดยแต่ละระดับความหนักจะยกน้ำหนักซ้ำจำนวน 15 ครั้ง จากการศึกษาพบว่าการเปรียบเทียบจากค่าเริ่มต้นภายในแต่ละกลุ่มอายุ อัตราการเต้นของหัวใจ (Heart rate) ในกลุ่ม 1, 2 และ 3 เพิ่มสูงขึ้นเมื่อออกกำลังกายด้วยเครื่อง shoulder press/lateral pull down, chest fly/reverse fly และ abdominal crunch/lower back extension ส่วนในกลุ่มที่มีอายุมากจะมีการใช้พลังงานสูงกว่ากลุ่ม 1 (จากเครื่อง shoulder press/lateral pull down และ chest fly/reverse fly ที่ความหนักระดับ 3 และ 4 ในกลุ่ม 3, $p<0.05$; และเครื่อง shoulder press/lateral pull down ที่ความหนักระดับ 2 ในกลุ่ม 4, $p<0.05$) แต่อย่างไรก็ดี ไม่พบความแตกต่างของการใช้พลังงานและการตอบสนองในระบบต่างๆ ระหว่างกลุ่มอายุในระหว่างการการออกกำลังซ้ำด้วยแรงต้านแบบไฮโดรลิกชนิดสองทาง ซึ่งสรุปได้ว่าเมื่อเพิ่มระดับความหนักในขณะออกกำลังกายซ้ำด้วยแรงต้านแบบไฮโดรลิกชนิดสองทางจะส่งผลให้ร่างกายมีการใช้พลังงานที่สูงขึ้น แต่อย่างไรก็ตามการศึกษานี้มีการออกกำลังกายอยู่ในระดับต่ำจึงทำให้ไม่พบความแตกต่างของการตอบสนองของระบบเมตาบอลิสมระหว่างการออกกำลังกายซ้ำด้วยแรงต้านแบบไฮโดรลิกชนิดสองทางในวัยต่างๆ

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คำสำคัญ: การใช้พลังงาน, การออกกำลังกายด้วยแรงต้านแบบไฮโดรลิกชนิดสองทาง, การใช้ออกซิเจน, การสร้างคาร์บอนไดออกไซด์

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สรีรวิทยาการออกกำลังกายและกีฬา (Sports and Exercise Physiology)

METABOLIC RESPONSES DURING REPEATED DOUBLE-HYDRAULIC RESISTANCE EXERCISES AMONG DIFFERENT AGED-GROUPS

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ABSTRACT

To investigate metabolic responses during repeated agonist–antagonist muscle contractions during double–hydraulic resistance exercises (DHRE), 32 healthy males volunteer participated in this study. They were selectively divided into four aged–groups of: Group 1 (gr1, 18–24 yrs), Group 2 (gr 2, 25–34 yrs), Group 3 (gr 3, 35–49 yrs) and Group 4 (gr 4, 50–59 yrs). Metabolic responses, via energy expenditures (EE) derived from oxygen consumption and carbon dioxide production, were assessed during repeated DHRE on five DHRE machines using progressive workload protocols from initial load (load 1, the lowest) to load 4 where subjects were asked to perform 15 repetitions at each workload. Within–group comparisons from initial values, heart rate responses increased in gr 1, 2 and 3 for shoulder press/lateral pull down, chest fly/reverse fly and abdominal crunch/lower back extension ($p<0.05$) with the exception in the aged group (gr 4). Energy expenditures were higher in the aged groups (shoulder press/lateral pull down and chest fly/reverse fly at load 3 and 4 in gr 3 ($p<0.05$); and shoulder press/lateral pull down at load 2 in gr 4, $p<0.05$). No significant differences for between–group comparisons in all variables for all exercises were detected ($p>0.05$). In conclusion, energy expenditures increase during repeated DHRE as a function of progressive workload. However, these metabolic responses were not different among aged–groups during repeated DHRE, which is possibly due to the low intensity used in this experiment.

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Keywords: Energy expenditure, Double–hydraulic resistance exercises, Oxygen consumption, Carbon dioxide production

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INTRODUCTION

Benefits of resistance exercise include well documented on health improvement and fitness, such as increases in muscular strength, cardiovascular fitness and body metabolism.[1] Manipulations of these 4 components have been done according to the training purposes. Muscle groups are overloaded through increase in loading, number of repetitions and sets. Resistance training can improve muscular strength, cardiovascular fitness and metabolic that depends on age, fitness level and health status.[2, 3] Conventionally, resistance exercise is usually done using free weights, multi–station weight machines, weight–stacks, pulley or cable systems and elastic resistance cable or tubing.[4] A popular type of resistance exercise includes free weights in which mass of a dumbbell or barbell remains constant and torque applied to the muscular system itself varies as lever length changes throughout a range of movement.[5] Resistance exercise equipment is reported to be safe and easy to use[3], in which it usually resists only agonist muscle group but fails to offer any physiologic activation on antagonist muscle groups. Therefore, those classical resistant machines do not allow the synchronize activation of agonist and antagonist muscles.

Modern machines, of either hydraulic or pneumatic, have been developed for beneficial variations of resistance and speed.[4] These special resistant training machines are reported to increase in maximum oxygen consumption, and cardiovascular variables (CVS) including stroke volume (SV), cardiac output (CO) with lower heart rate (HR) responses.[6] Previous studies compared 20 minutes circuit weight training to single hydraulic training machine and found that hydraulic machines induced 20–35% higher energy expenditure.[7, 8] In terms of cardiac and metabolic responses, VO_2 (oxygen consumption) and heart rate in hydraulic exercises were higher than reported from other types of circuit weight training machines.[7] However, the above single hydraulic resistant machines offer only agonistic muscle action, but not for antagonistic muscle action. Recently, double–hydraulic resistance machines have been developed to permit alternated action of both agonist and antagonist muscle action.

Changes in physiologic system depend upon type and quality of resistance training, which must be varied according to age and levels of physical ability.[6] Previous studies found that single hydraulic machine produced higher energy expenditure than other types of weight training in adolescent with increasing in stroke volume, cardiac output and heart rate in adolescent and middle–age. The energy expenditure for single hydraulic machines induced 35% greater than exercise with free weights[9] and 10–23% higher than circuit training.[8] Up to our knowledge, there is no report about outcome on metabolic responses from exercise in different aged–groups using double hydraulic machines. It is hypothesized that aging might induce different metabolic responses during exercise of pairs of agonist–antagonist muscle actions. The present study is aimed to investigate metabolic responses, in term of gas exchanges, of agonist–antagonist muscles exercise among aged–groups.

METHOD

Subject

The inclusion criteria were aged between 18–59 years, healthy–sedentary males, participated in physical activity or sports less than 2 times per week and voluntarily participated in this study. The sedentary males, who had cardiovascular diseases, hypertension, respiratory diseases and musculoskeletal injuries, were excluded. Subjects were divided, according to ages, into 4 groups: group 1 (18–24 years, n =8), group 2 (25–34 years, n =8), group 3 (35–49 years, n =8), and group 4 (50–59 years, n =8). After screening processes via physical activity questionnaire and physical examination, subjects were informed about experimental protocol, procedure, possible risks and benefits of this study. Thereafter, informed consent form was signed according to the Human Ethics Committee on Human Experimentation of Mahidol University.

Experimental procedure

Subjects of 4 different aged–groups visited the laboratory where the orders of 5 stations of double hydraulic resistant machine from Marathon (Thailand) Co., Ltd. that included leg curl/leg extension, shoulder press/lateral pull down, chest fly/reverse fly, abdominal crunch/lower back extension and rotary torso machines, were randomly assigned. Subject had to exercise on each station, consisted of two sets of double hydraulic resistance, which was serially arranged from the same lowest toward the same highest workloads. For example, first set was conducted at the same levels of double–hydraulic resistant starting at 1/1 (agonist/antagonist) which then progresses to 2/2, 3/3 etc. Subject was asked to continuously perform 15 repetitions per load where a 1–to–1 work/rest ratio, controlled from a metronome. Subject was allowed for full recovery, using resting heart rate, and continued exercise on the same station at the stepwise pattern up to the highest workload. This progressive exercise patterns were continued up to resistance of level 4. Physiological characteristics consisted of cardiovascular and energy expenditure profiles were continuously recorded, of either at rest or during exercises. Physiological variables included heart rate, oxygen consumption and carbon dioxide production were measured from indirect calorimetry using Oxycon mobile portable metabolic system. Energy expenditures were calculated from oxygen consumption and carbon dioxide production at each step.[10,]

Statistical analysis

All data were presented as mean ±SEM. Normal distribution was tested using Shapiro–Wilk test. Between–groups and within–group were tested using one–way repeated ANOVA measurement. The statistical tests were performed using a SPSS software program. Significance was set at *p*–value less than 0.05.

RESULT

Anthropometric profiles

Anthropometric profiles were presented (Table 1) including age, body weight, height, and body mass index (BMI). There were significantly different of mean ages between all groups (p<0.05), body weights were significantly different between group 1–group 4 (p<0.05) and group 3–group 4 (p<0.05), heights were significant different between group 1–group 3(p<0.05), group 1–group 4(p<0.05), group 2–group 3 (p<0.05) and group 2–group 4 (p<0.05) and BMI were significantly different between group 1–group 4 (p<0.05), group 2–group 4 (p<0.05), and group 3–group 4 (p<0.05).

Table 1 Anthropometric profiles of 4 groups divided according to ages.

Variables	Group 1	Group 2	Group 3	Group 4
Age (yrs)	21.38 ±0.68	26.13 ±0.35	42.88 ±1.39	53.63 ±1.08
Body weight (kg)	65.90 ±2.32	68.88 ±2.91	65.71 ±3.72	75.74 ±3.75 ^{c,f}
Height (cm)	173.25 ±1.96	171.50 ±1.10	164.63 ±1.66 ^{b,d}	164.25 ±1.25 ^{c,e}
BMI (kg·m^2)	21.87 ±0.59	23.40 ±0.97	24.14 ±1.18	28.05 ±1.33 ^{c,e,f}

Abbreviations: a represents significant different between group 1 and 2; b significant different between group 1 and 3; c significant different between group 1 and 4; d significant different between group 2 and; e significant different between group 2 and 4; f significant different between group 3 and 4. All comparisons are set at p<0.05.

Resting physiological characteristics

Resting physiological characteristics include profiles of cardiovascular and energy expenditures were presented (Table 2) with no significant differences of either within or between groups were detected.

Table 2 Resting physiological characteristics of subjects in all groups.

Variables	Group 1	Group 2	Group 3	Group 4
HR (bpm)	76.27 ±2.80	72.77 ±1.33	79.50 ±4.26	73.82 ±2.75
EE (Cal/min)	1.91 ±0.91	2.03 ±0.32	1.85 ±0.28	2.19 ±0.15

Heart rates during exercise

Heart rate profiles among all groups are presented from leg curl/leg extension (Figure 1A), shoulder press/lateral pull down (Figure 1B), chest fly/reverse fly (Figure 1C), abdominal crunch/lower back extension (Figure 1D) and rotary torso machines (Figure 1E). HR responses were not different among aged–groups during repeated DHRE. Exercises HR values were significantly different from the corresponding initial levels as follows: in group 1, 2, and 4 (p<0.05) for leg curl/leg extension (Figure 1A); in group 1, 2, and 3 (p<0.05) for shoulder press/lateral pull down (Figure 1B) and chest fly/reverse fly (Figure 1C); in group 2 (p<0.05) for abdominal crunch/lower back extension (Figure 1D) and HR from rotary torso (Figure 1E).

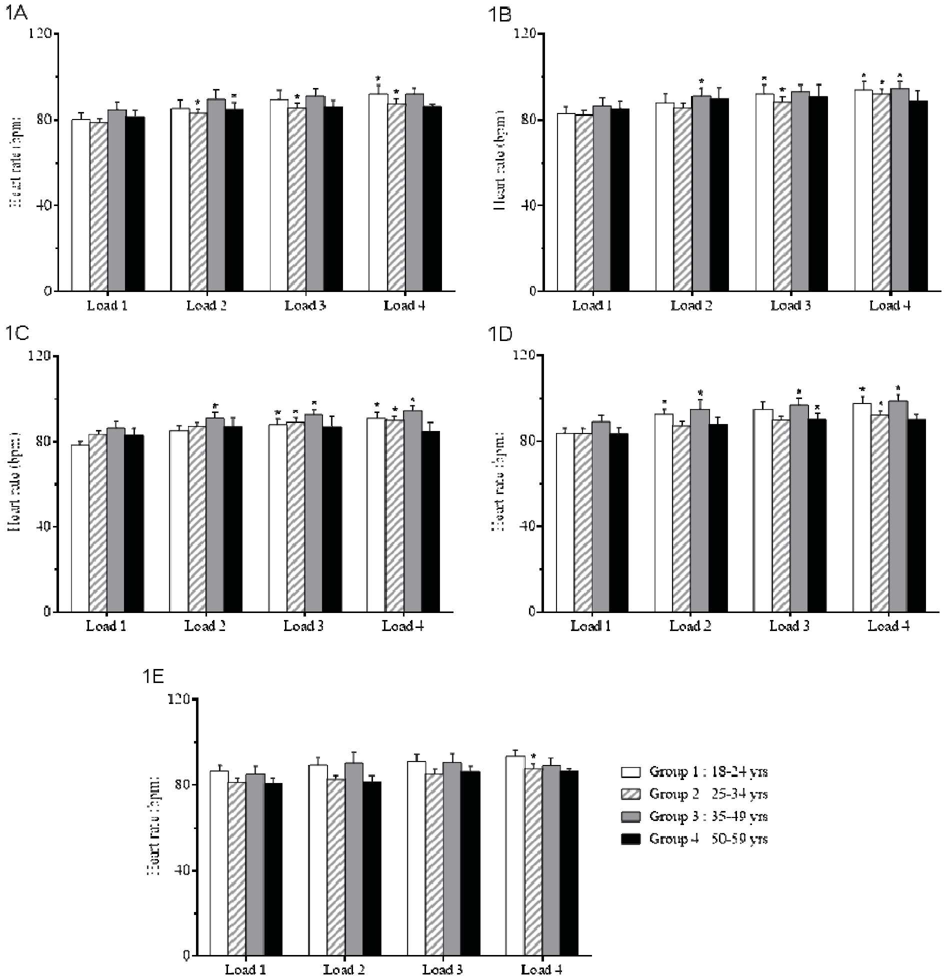

Figure 1 Exercise heart rates of group 1, 2, 3 and 4 from leg curl/leg extension (1A), shoulder press/lateral pull down (1B), chest fly/reverse fly (1C), abdominal crunch/lower back extension (1D) and rotary torso machines (1E).machines obtained from progressive resistance workout from an initial (load 1) workload. *Significant different from initial value of that group (p<0.05). [a] Significant different between group 1 and 2 (p<0.05). [b] between group 1 and 3 (p<0.05). [c] between group 1 and 4 (p<0.05). [d] between group 2 and 3 (p<0.05). [e] between group 2 and 4 (p<0.05). [f] between group 3 and 4 (p<0.05).

Energy expenditures during exercise

There were significantly different from the initial EE as follows: in group 3, and 4 (p<0.05) for shoulder press/lateral pull down (Figure 2B); in group 1, and 3 (p<0.05) for abdominal crunch/lower back (Figure 2D). However, these EE were not different among aged–groups during repeated DHRE.

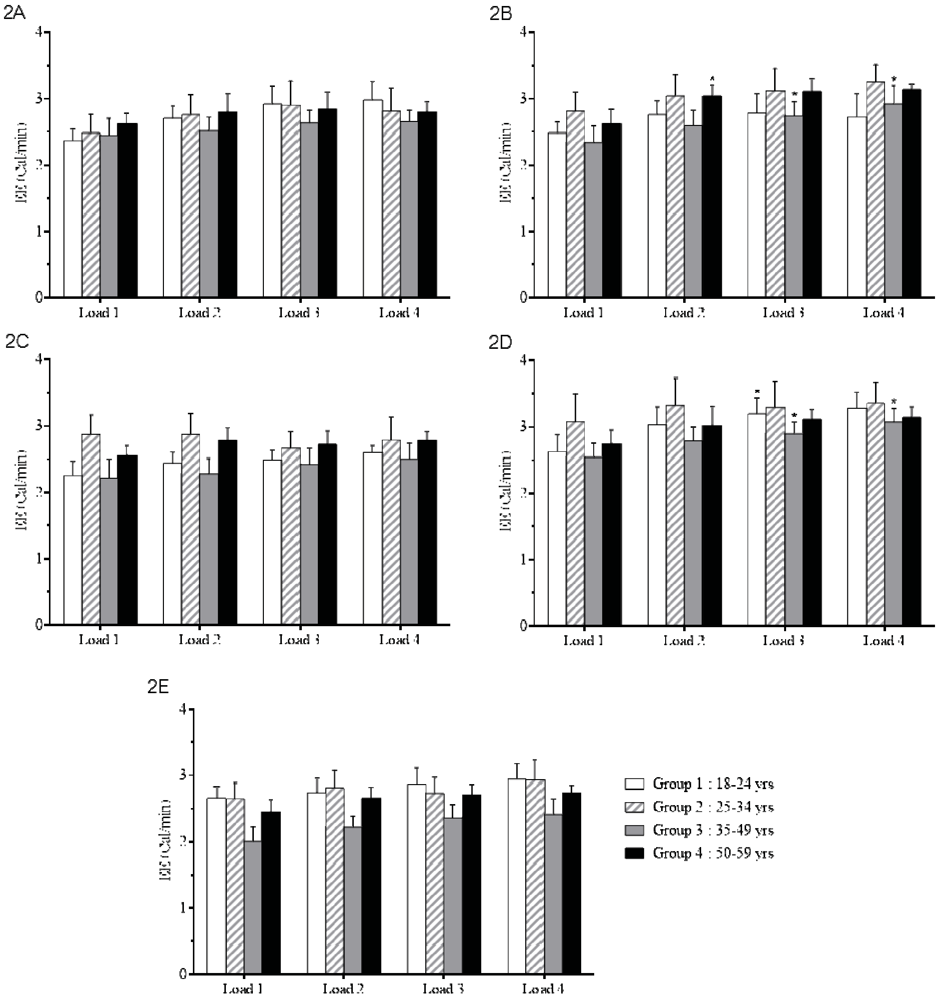

Figure 2 Energy expenditure of group 1, 2, 3 and 4 from leg curl/leg extension (2A), shoulder press/lateral pull down (2B), chest fly/reverse fly (2C), abdominal crunch/lower back extension (2D) and rotary torso machines (2E).machines obtained from progressive resistance workout from an initial (load 1) workload. *Significant different from initial value of that group (p<0.05). [a] Significant different between group 1 and 2 (p<0.05). [b] between group 1 and 3 (p<0.05). [c] between group 1 and 4 (p<0.05). [d] between group 2 and 3 (p<0.05). [e] between group 2 and 4 (p<0.05). [f] between group 3 and 4 (p<0.05).

DISCUSSION

HR responses in all groups showed trends of increasing with progressive workloads and there were significantly different within each group during exercise using all double–hydraulic resistance machines. These results showed that exercise using all double–hydraulic resistance machines could elevate the HR when exercised in higher load or progressive workloads. This was also similar to increasing the HR from acute anaerobic exercises.[12] Even at highest workload (load 4) in this study, heart rate changes are not over than 100 bpm. This revealed that workloads used in the present study were not intense enough to induce any cardiac stress.

Accordingly, resting energy expenditure ranges about 1 Cal/min, this will reflect that 2–4 Cal/min EE during double–hydraulic resistance exercises are classified as light intensity.[13] Greater EE is derived at higher workload, repetitions and numbers of muscle involved.[14, 15] This study confirms that EE is greater whenever more numbers of big muscles involved in exercises. That according to oxygen consumption and carbon dioxide production during exercise. This is particularly true for shoulder press/lateral pull down and abdominal crunch/lower back machines. Numbers of repetition, sets and velocity for resistance exercises are among factors affecting physical performance that included repeat resistance exercise would decrease ability of muscles.[16] Thus 15 repetitions used in this study will affect muscle ability, particularly when alternated contractions were governed at 1 sec interval via a metronome. However, with lower heart rate and no significant differences of energy spent among aged–groups revealed that despite the lower muscle ability, cardiac stress remained low for all double–hydraulic resistance machines.

CONCLUSION

The present study on metabolic and physiological profiles responses during progressive workload exercises using double–hydraulic resistance machines can be concluded that: Cardiovascular profiles, heart rate as an example, increased as function of progressive workload in all aged groups with the exception in the oldest group. This aged group responses within the limited heart rate range no matter which workload is being used. The metabolic responses, represented as energy expenditures, showed trends of increasing when exercises in progressive workloads, which are remarkably found in aged groups, in particular group 3. Furthermore, the results from this study showed that ageing does not effect on progressive double–hydraulic resistance machines as indicated by unchanged in energy expenditure and cardiovascular system.

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