การออกกำลังกายในน้ำแบบเป็นช่วงเพื่อเพิ่มปริมาณการใช้ออกซิเจนสูงสุดและความสามารถของการออกกำลังกายในคนอ้วน

Aquatic Interval Training for the Improvement of Peak Oxygen Uptake and Functional Exercise Capacity in Obesity

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บทคัดย่อ

วัตถุประสงค์ การศึกษานี้มีวัตถุประสงค์เพื่อประเมินผลของการออกกำลังกายในน้ำแบบเป็นช่วงต่อปริมาณการใช้ออกซิเจนสูงสุดและความสามารถของการออกกำลังกาย (ระยะทางจากการทดสอบเดิน 6 นาที) ในกลุ่มคนอ้วน วิธีดำเนินการวิจัย คนอ้วนที่ทำกิจกรรมระดับหนักปานกลาง น้อยกว่า 30 นาที น้อยกว่า 3 วัน/สัปดาห์ ในช่วง 3 เดือนที่ผ่านมา เข้าร่วมในการศึกษานี้จำนวน 21 คน ผู้เข้าร่วมการวิจัยถูกสุ่มแบ่งออกเป็น 2 กลุ่มคือ กลุ่มควบคุม (เพศหญิง 5 คน เพศชาย 5 คน อายุ 38.6 ± 9.68 ปี ดัชนีมวลกาย 31.77 ± 4.73 กก./ม.^{2}) และกลุ่มทดลอง (เพศหญิง 6 คน เพศชาย 5 คน อายุ 33.73 ± 9.13 ปี ดัชนีมวลกาย 30.96 ± 3.47 กก./ม.^{2}) กลุ่มทดลองได้รับโปรแกรมการออกกำลังกายในน้ำแบบเป็นช่วงที่ความหนักร้อยละ 60-75 ของชีพจรสำรอง โดยออกกำลังกายในน้ำ 3 ครั้ง/สัปดาห์ ต่อเนื่องกัน 6 สัปดาห์ ผู้เข้าร่วมการวิจัยกลุ่มควบคุมได้รับโปรแกรมการยืดกล้ามเนื้อด้วยตนเองที่บ้าน ทำต่อเนื่องกัน 6 สัปดาห์ วัดปริมาณการใช้ออกซิเจนสูงสุดและระยะทางจากการทดสอบเดิน 6 นาทีของผู้เข้าร่วมการวิจัยก่อนและหลังเข้าร่วมโปรแกรมการออกกำลังกาย ผลการวิจัย พบว่าผู้เข้าร่วมการวิจัยในกลุ่มทดลองมีปริมาณการใช้ออกซิเจนสูงสุดเพิ่มขึ้นร้อยละ 8.66 *(p = 0.003)* และระยะทางจากการทดสอบเดินจับเวลา 6 นาทีเพิ่มขึ้นร้อยละ 10.30 (p = 0.002) เมื่อเปรียบเทียบกับกลุ่มควบคุม ข้อสรุป การออกกำลังกายในน้ำแบบเป็นช่วงต่อเนื่องกันเป็นเวลา 6 สัปดาห์ ส่งผลให้กลุ่มคนอ้วนมีปริมาณการใช้ออกซิเจนสูงสุดและระยะทางจากการทดสอบเดินจับเวลา 6 นาทีเพิ่มขึ้น ซึ่งโปรแกรมการออกกำลังกายนี้อาจเป็นอีกทางเลือกหนึ่งที่นำไปปรับใช้กับกลุ่มคนอ้วนเพื่อเพิ่มสมรรถภาพของระบบหัวใจและหายใจได้

คำสำคัญ: *คนอ้วน, การออกกำลังกายในน้ำแบบเป็นช่วง, การออกกำลังกายในน้ำ, ปริมาณการใช้ออกซิเจนสูงสุด*

Abstract

Objective: This study aimed to assess the effects of aquatic interval training on peak oxygen uptake (VO_{2peak}) and functional exercise capacity (6-minute walk distance: 6MWD) in obesity. Twenty-one sedentary obese individuals were randomly assigned to a control (n = 10, 5 females and 5 males, age 38.6 ± 9.68 years, BMI 31.77 ± 4.73 kg/m^2) and a training group (n = 11, 6 females and 5 males, age 33.73 ± 9.13 years, BMI 30.96 ± 3.47 kg/m^2). The training group performed high intensity aquatic interval training at 60-75 percents of heart rate reserve (HRR) 3 sessions per week for a total of 6 weeks. Participants in the control group received a home program of self-stretching exercise for 6 weeks. Indirect VO_{2peak} and 6MWD were measured before and after the training period. Results: The trained obesity had 8.66 percents (p = 0.003) and 10.30 percents (p = 0.002) higher VO_{2peak} and 6MWD, respectively compared with the control group. Peak oxygen uptake increased by 6.96 percents (p = 0.005) and 6MWD increased by 8.47 percents (p = 0.002) compared within the training group. In conclusion, a six-week aquatic interval training contributes to an increase in VO_{2peak} and 6MWD in obesity. Therefore, this aquatic interval training program would have another modality to apply in obese population for enhancing cardiorespiratory fitness.

Keywords: *Obesity, Aquatic interval training, Water-based exercise, Peak oxygen uptake*

1. Introduction

The prevalence of obesity is an important public health concern worldwide, as it rapidly increased and risked men and women alike for the diseases such as progressive cardiovascular disease (CVD), metabolic disorders, and other chronic non-modified diseases (Pasetti, Gonçalves, & Padovani, 2012; Rica et al., 2013). In Asian context, body mass index (BMI) ≥ 25 kg/m^2 is used to classify for obese adults (Weisell, 2002). In Thailand, the prevalence of obese adults was 28.1 percents in 2004. Of these, the highest rate of obesity was reported in the age of 45-54 years in both gender (Aekplakorn & Mo-Suwan, 2009). The rate of abdominal obese population with age > 15 years was found as 36.48 percents in 2010 (Health, 2014). Two past meta-analysis studies have shown that obesity (evaluated as BMI) resulted in independently increased risk of the mortality 20 percents in women and 28 percents in men (Barry et al., 2014). It has been quite cleared that the progressive increase in BMI is associated with an decrease in maximal oxygen uptake (VO_{2max}) (Arena & Cahalin, 2014; Pandey et al., 2014; Radovanovic et al., 2014; Sood, 2009), and the increase with each 3.5 ml/kg/min of oxygen uptake is associated with a 13 percents and 15 percents decreased in all-cause mortality and CVD, respectively (Arena & Cahalin, 2014; Barry et al., 2014).

Over the past decade, high intensity interval training (HIIT) has become a central focus of health related researches (Lau et al., 2015) and is extensively used to gain aerobic performance and improve health (Pasetti et al., 2012; Zuniga et al., 2011). Although the HIIT has significantly increased VO_{2max} compared with continuous training in obesity (Hwang, Wu, & Chou, 2011; Ingul, Tjonna, Stolen, Stoylen, & Wisloff, 2010) but there is still controversy in several studies (Fisher et al., 2015; Pasetti et al., 2012). The benefit of interval training has contributed to an increase in the total volume of high intensity exercise that can be done during an exercise session (ACSM, 2014; Zuniga et al., 2011). Besides an active recovery during the HIIT session, it has greatly improved and accelerated the removal of blood lactate level preventing lactate accumulation and probably extensively increased the tolerable exercise time (Hwang et al., 2011; Zuniga et al., 2011). Although HIIT in obesity can be performed in either land-based (Bækkerud et al., 2015; Fisher et al., 2015; Hwang et al., 2011; Ingul et al., 2010) or water-based environment (Pasetti et al., 2012), land-based exercise such as running, may be presented in musculoskeletal injury. Hence, alternative training modalities such as water-based exercise are frequently used to maintain a functional capacity (Quinn, Sedory, & Fisher, 1994). It is considered as the safest and most protective training environment for obesity, because the buoyancy of water reduces the risk of injury to joints (Becker, 2009; Meredith-Jones, Legge, & Jones, 2009).

This current study focuses on the benefits of HIIT in water, may be useful for further investigation on the effects of aquatic interval training on VO_{2peak} and functional exercise capacity in obese adults. There were studies reporting on the effects of water-based exercise in cardiorespiratory fitness (CRF) in obesity (Greene et al., 2009; Meredith-Jones et al., 2009; Rica et al., 2013) but rare in the study of HIIT in water environment, particularly in obesity (Boidin et al., 2015; Pasetti et al., 2012). Although the studies of Boidin et al and Pasetti et al demonstrated the effectiveness of HIIT in water for obesity, but there was no study reported the short-term effects of HIIT in water for the corresponding population. The researchers hypothesize that the trained obese participants would have significantly increased VO_{2peak} and 6MWD compared to the control group.

2. Objective

The purpose of this study was to assess the short-term effects of aquatic interval training on VO_{2peak} and functional exercise capacity (6MWD) in obesity.

3. Materials and methods

3.1 Participants

Participants were invited through notices and verbal. They were recruited from two hospitals and two senior organizations in Sattahip, Chonburi, Thailand. The selected participants met the following criteria: BMI ≥ 25 kg/m^2, age between 25 to 55 years, sedentary people (< 30 minutes of physical activity with moderate intensity, at least 3 day/week for at least the 3 months), and able to perform an activity in each session of aquatic training more than 60 minutes. Twenty-one sedentary obese participants (11 females, 10 males, age 36.19 ± 9.53 years, BMI 31.34 ± 4.03 kg/m^2, weight 89.12 ± 17.57 kg, height 168.19 ± 10.58 cm) participated in the study. A screening questionnaire (health and life style) was used to investigate their health by a face-to-face interview. Participants who had medical history of coronary artery disease or unstable angina and pulmonary problems, uncontrolled metabolic diseases, uncontrolled hypertension, orthopedic problems, other severe condition, participated in any another clinical trial, and history of smoking included in the exclusion criteria. The Baecke habitual physical activity questionnaire (Thai version) (Baecke, Burema, & Frijters, 1982; Jalayondeja et al., 2015) was applied to confirm that all participants were in a sedentary group. This study was approved by the Research Ethics Review Committee for Research Involving Human Research Participants, Health Sciences Group from Chulalongkorn University, Thailand. All participants provided their written informed consent before participating in the study.

3.2 Study design

This study was a single blinded and two-arm parallel block randomized control trial investigating the effects of a six-week aquatic interval training on VO_{2peak} and functional exercise capacity (6MWD) in obesity. Eligible participants who met the inclusion and the exclusion criteria were randomly allocated to either a control or a training group. Obese participants in the experimental group received a six-week aquatic interval training. The control group undertook a self-stretching exercise program.

3.3 Materials

The instruments in this study included automatic blood pressure monitors (Omron HEM-7203, Kyoto, Japan), pulse oximeter (Edan, H10 Fingertip oximeter, White Medical, Rugby, UK), the Borg scale of perceived exertion chart, measuring tape, traffic cones, digital stopwatch (SEIKO Memory 100, Japan), stadiometer (Seca, Hamburg, Germany), body composition monitor with scales (Omron, KaradaScan HBF-362, Kyoto, Japan), Baecke Habitual Physical Activity questionnaire (Thai version), heart rate monitor (Sigma PC 3.11, Germany) and life vests.

3.4 Procedures

Outcome measurements were measured at before and after training period (within 3 days) by secondary investigators who were blinded the participant's information. Moreover, all participants were required to maintain their physical activity level, usual dietary intake and alcohol consumption throughout this study.

3.4.1 Peak oxygen uptake and six-minute walk distance

Six-minute walk test (6MWT) was opted for measuring the predicted VO_{2peak}. The test was conducted according to the American Thoracic Society (ATS) recommendation (ATS, 2002). Participants were required to walk back and forth along the 30-meter hallway as fast as they can within 6 minutes. They were instructed to wear comfortable clothes with sport shoes. Strenuous activity should be avoided for 24 hours before the test and avoided a heavy meal and caffeine for 2 to 3 hours prior to testing. VO_{2peak} expressed as ml/kg/min and predicted from the equation according to American College of Sport Medicine (ACSM)'s guidelines (ACSM, 2014). The distance from the testing was presented in meter.

3.4.2 Aquatic interval training

The interval training protocol published by Bækkerud et al. (Baekkerud et al., 2016) was adopted with slight modification. Aquatic interval training consisted of 3 days a week for a total of 6 weeks. Each training session composed of 3 stages. The first stage was a warm-up included running in the water for 10 minutes at 50 percents of HRR. The second stage was a HIIT included 4 minutes of running in the water at 60-75 percents of HRR interspersed with 3 minutes of active recovery at 50 percents of HRR. Each 3-minute active recovery phase included 2 primary exercises: 1) star jumps performed in 1st, 3rd, 5th and 7th cycle, and 2) forward jumps performed in 2nd, 4th and 6th cycle. The final stage was a 3-minute cool down at 50 percents of HRR.

Exercise intensity was prescribed at 60-65 percents of HRR and HIIT was performed with 5 cycles in the first two weeks. Then, the target of training intensity progressed to 65-70 percents of HRR and HIIT performed 6 cycles in 3rd to 4th week. In the last 2 weeks, participants performed 7 cycles of HIIT at 70-75 percents of HRR. They were required to attach HR monitor on their chest wall and wrist joint, and worn life vest throughout the exercise sessions. Average HR was checked every 1 minute and recorded immediately in the last minute of each exercise session by the researcher to ensure prescribed intensities reached to target zone. Participants who were unable to attend in those training more than 15 sessions out of 18 sessions were excluded from the data analysis.

3.4.3 Stretching exercise program

Obese participants in control group received a home program of 3 times/week self-stretching exercise. After 6 weeks, they achieved the instruction of aerobic exercise program according to the guidelines recommended by the ACSM (ACSM, 2014) for obese adults.

3.5 Statistical analysis

All data are expressed as mean and standard deviation (SD). The differences between groups at baseline were assessed using unpaired *t*-test. Paired *t*-test was used to compare the overall pre-post differences within a group. The analysis assessed the treatment effect on the change over time using an analysis of covariance (ANCOVA) model with the baseline outcome value as covariates. All statistical analyses were performed using IBM SPSS statistical software version 22.0, and p values < 0.05 was considered as statistically significant.

4. Results

Twenty-one sedentary obese participants enrolled and were allocated to control (n = 10, 5 females, 5 males) and experimental group (n = 11, 6 females, 5 males). Baseline characteristics of the control and the experimental group are summarized in Table 1. No statistically significant baseline differences were observed.

Table 1 Baseline characteristics between control and experimental group (mean ± SD).

Variable	Control (n = 10)	Experimental (n =11)	*p*-Value
Age (year)	38.60 ± 9.65	33.73 ± 9.13	0.250
Height (cm)	166.80 ± 9.86	169.46 ± 11.51	0.579
Body weight (kg)	88.65 ± 18.16	89.55 ± 17.90	0.911
BMI (kg/m^2)	31.770 ± 4.73	30.96 ± 3.47	0.655

In aquatic interval training group, nine from eleven participants completed all their prescribed training sessions. One female attended 17 from all 18 sessions. One male withdrew from the training group after attained 8 sessions due to a motorcycle accident, caused a fractured left humerus. There were no adverse events during the training. Nevertheless, seven participants (4 females, 3 males) reported a tension at the calf muscles in the first week of exercise. The mean exercise training intensity was 98.98 ± 3.54 percents, 99.32 ± 2.2 percents, and 98.37 ± 1.81 percents of 65 percents HRR, 70 percents HRR, and 75 percents HRR, respectively.

For the primary analysis, ANCOVA models comparing change scores between each group found a significant difference in VO_{2peak} and 6MWD improvement between control and experimental groups. After aquatic interval training, the trained obese had 8.66 percents or 2.04 ± 1.44 ml/kg/min ($p = 0.003$) and 10.30 percents or 45.80 ± 32.39 m ($p = 0.002$) higher VO_{2peak} and 6MWD compared with the control group. In addition, VO_{2peak} and 6MWD in the experimental group had significantly increased by 6.96 percents or 1.30 ± 0.92 ml/kg/min ($p = 0.005$) and 8.47 percents or 47.40 ± 33.52 m ($p = 0.002$) compared to the prior-training period. No significant differences of VO_{2peak} and 6MWD were found among the control group. All exercise variables are summarized in Table 2.

5. Discussion

The purpose of this study was to assess the effects of aquatic interval training on VO_{2peak} and functional exercise capacity (6MWD) in obesity. The primary findings from the present study were that obese participants randomly allocated to six weeks of aquatic interval training had a significantly higher improvement in VO_{2peak} and 6MWD as compared to the control group. Among the training group, VO_{2peak} and 6MWD had a greater extent after the program. No changes were observed in VO_{2peak} or 6MWD from pre- to post training in the control group. These current findings supported our hypothesis in this study. To our knowledge, our study is the first to report the short-term effects of aquatic interval training in obese adults, and the results of the present study suggest that a 6-week of aquatic interval training can lead to an improve in VO_{2peak} and 6MWD for obese men and women.

Peak oxygen uptake increased by 8.66 percents after accomplished the program, indicating that CRF can be progressed in a 6-week of aquatic interval training. This finding has an important clinical implication with previous studies indicated that low levels of CRF are known to be as an independent predictor for cardiovascular mortality and all-causes mortality (Arena & Cahalin, 2014; McAuley & Beavers, 2014). The improvement in VO_{2peak} is comparable to that found by Broman et al. studied a group of overweight women who participated in 8 weeks of HIIT (75 percents of maximal HR) in deep water, and despite longer duration of the program, found similar higher in maximal oxygen uptake (VO_{2max}) (Broman, Quintana, Lindberg, Jansson, & Kaijser, 2006). There was also a study of Boidin et al., where obese patients performed a 9-month of HIIT (80 percents of maximal aerobic power: MAP) with a water-immersed ergocycle, similarly enhanced in maximal aerobic capacity was observed as well (Boidin et al., 2015).

Table 2 Body composition and cardiorespiratory fitness variables over time (mean ± SD).

Variables	Control group (n = 10)		Experimental group (n = 10)	
	Before	**After**	**Before**	**After**
Body weight (kg)	88.65 ± 18.16	88.93 ± 17.62	88.76 ± 18.66	88.49 ± 18.19
BMI (kg/m^2)	31.77 ± 4.73	31.87 ± 4.76	31.08 ± 3.63	31.04 ± 3.60
VO_{2peak} (ml/kg/min)	18.24 ± 2.02	17.93 ± 1.85*	18.67 ± 2.27	19.97 ± 2.95**
6MWD (m)	571.90 ± 47.04	561.40 ± 54.25*	559.80 ± 43.89	607.20 ± 64.16**

* Significant between control and experimental group ($p < 0.05$), ** Significant difference between before and after training ($p < 0.05$).

The adaptation in VO_{2peak} due to aquatic interval training is found mostly in peripheral skeletal muscles, with higher levels of arteriovenous oxygen ($a\text{-}\bar{V}\,O_2$) difference, increased in central blood flow, and increased in mitochondrial enzyme activities (Bassett & Howley, 2000; Broman et al., 2006). When the body is immersed in water, the hydrostatic static vascular gradient may additionally contribute to increase central blood volume by regulating intrathoracic pressures (Reilly, Dowzer, & Cable, 2003). An alteration of central blood flow leads to elevated cardiac output as a result of a higher stroke volume (Broman et al., 2006; Reilly et al., 2003). This increase has been attributed to a higher level of diastolic filling. Hydrostatic compression resulted in the transcapillary fluid shifts. The greater thoracic blood volume enhanced the ability to stretch of the heart wall, and decreased sympathetic nerve activity (Reilly et al., 2003). These results possibly increase the stimulation of the myocardium to adapt to training (Broman et al., 2006).

Although the reported by Larsson and Reynisdottir regarding the assessed reproducibility and validity of 6MWT in men and women with obesity, the clinically significant difference required of 6MWD was at least 80 meters for evaluation (Larsson & Reynisdottir, 2008). This study demonstrated that the distance from 6MWT had significantly increased by 10.3 percents ($p = 0.002$) after the training between training and control groups. A significant increment of 6MWD by 45.80 ± 32.39 meters would be as a result from the adaptation in CRF due to a short-term of aquatic interval training. This improvement was in line with our hypothesis.

The strength of this study included the participants who were recruited from both genders, had a control group for the comparison of the interaction effects, no dietary restriction and no lifestyle modification in all participants. Moreover, baseline and final outcome measurements were investigated by the secondary investigators who blinded the group of participants. Despite 6MWT is considered as a submaximal exercise test, and as an indirect method for estimation the levels of VO_{2peak}, several multivariate equations are available to predict VO_{2peak} from this test (ACSM, 2014). Nevertheless, the limitation in this study was the state of research setting which was set at an outdoor swimming pool; we were unable to control the weather conditions. However, the water temperature while performing in each aquatic exercise session was not quite different (28-30 ºC). For future research strategies, first, the gas analyzer should be conducted for a global evaluation of the progressive exercise response, and providing direct results of VO_{2peak}. Second, satisfaction and enjoyment should be investigated for development in modified activities during the performing of interval and recovery periods. Third, anthropometric assessments should be added in the outcome measurements to increase the positive motivation of obese participants.

In Summary, improving or maintaining CRF is associated with a reduction in the risk of CVD morbidity, and premature deaths from all-cause. The present study demonstrated that a 6-week of aquatic interval training has been given to improve CRF and functional exercise capacity in obese adults, which corresponded to the hypotheses of this study. In addition to this program, the sedentary obese adults according to the mean exercise intensity (over 95 percents of target HRR) were well tolerated.

6. Conclusion

Six weeks of aquatic interval training with the intensity at 60-75 percents of HRR contributes to significantly increase VO_{2peak} (8.66 percents) and 6MWD (10.30 percents) in obese man and woman. A greater improvement was observed in VO_{2peak} (6.96 percents) and 6MWD (8.47 percents) from pre- to post training in the experimental group. No significant differences of VO_{2peak} and 6MWD were found in the control group. These results indicated that the protocol in this study would be another modality to be applied in obesity to enhance the CRF.

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