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Physiological responses to Tai Chi in stable patients with COPD

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ABSTRACT

We compared the physiological work, judged by oxygen uptake, esophageal pressure swing and diaphragm electromyography, elicited by Tai Chi compared with that elicited by constant rate treadmill walking at 60% of maximal load in eleven patients with COPD (Mean FEV_1 61% predicted, FEV_1/FVC 47%). Dynamic hyperinflation was assessed by inspiratory capacity and twitch quadriceps tension (TwQ) elicited by supramaximal magnetic stimulation of the femoral nerve was also measured before and after both exercises.

The EMGdi and esophageal pressure at the end of exercise were similar for both treadmill exercise and Tai Chi (0.109 ± 0.047 mV vs 0.118 ± 0.061 mV for EMGdi and 22.3 ± 7.1 cmH_2O vs 21.9 ± 8.1 cmH_2O for esophageal pressure). Moreover the mean values of oxygen uptake during Tai Chi and treadmill exercise did not differ significantly: 11.3 ml/kg/min (51.1% of maximal oxygen uptake derived from incremental exercise) and 13.4 ml/kg/min (52.5%) respectively, $p > 0.05$. Respiratory rate during Tai Chi was significantly lower than that during treadmill exercise. Both Tai Chi and treadmill exercise elicited a fall in IC at end exercise, indicating dynamic hyperinflation, but this was statistically significant only after treadmill exercise. TwQ decreased significantly after Tai Chi but not after treadmill.

We conclude that Tai Chi constitutes a physiologically similar stimulus to treadmill exercise and may therefore be an acceptable modality for pulmonary rehabilitation which may be culturally more acceptable in some parts of the world.

1. Introduction

Pulmonary rehabilitation (PR) is a therapy of proven efficacy in Chronic Obstructive Pulmonary Disease (COPD) (Griffiths et al., 2000), but classical PR entails the provision of centralized facilities with dedicated exercise equipment and staff. This can limit uptake of this therapy both because it confers a finite limit to the number of patients that can be treated at any one time, and because patients may find travelling to a central facility a deterrent (O'Shea et al., 2007; Keating et al., 2011). Secondly, where PR can only be given for fixed periods a detarining effect occurs so that both exercise capacity and quality of life usually decline gradually after completion of PR (Griffiths et al., 2000).

Tai Chi is a traditional form of exercise developed in China, originally as a martial art for combat purposes. Tai Chi consists of a series of slow but continuous movements of many parts of the body. There is experimental evidence from both cross-sectional and longitudinal studies that Tai Chi exercise has beneficial effects on cardiovascular fitness (Chang et al., 2011), balance control and psychological well-being (Chyu et al., 2010). Since the movements can be adapted to suit people with physical weaknesses or disabilities, Tai Chi has become increasingly popular among elderly people in Hong Kong, mainland China, and other parts of the world (Wang et al., 2010; Li et al., 2012; Leung et al, 2013).

Tai Chi could therefore potentially replace western style PR with the advantages both that class sizes are not limited by the quantity of specialized exercise equipment and that the patient may continue the exercise at home after the end of formal training. However, whilst the clinical studies noted above support the value of Tai Chi, some physiologic questions remain unanswered. First, no study has assessed respiratory mechanics during Tai Chi probably because of the difficulty recording esophageal pressure and EMGdi during free movement. Consequently, it is unknown what level

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of respiratory load is elicited by this therapy. In particular, since Tai Chi requires control of breathing during exercise we hypothesized that this may reduce breathing frequency and thus confer a beneficial effect on dynamic hyperinflation compared with treadmill exercise. Secondly it is unknown whether Tai Chi is sufficient to elicit low frequency quadriceps fatigue, which would indicate that the exercise is sufficiently intense to produce a training effect (Mador et al., 2001). To address these questions we undertook a detailed physiological comparison of 24-form Yang style Tai Chi, the most widely practiced style today, and constant rate treadmill walking.

2. Methods

Eleven patients with COPD (age 62 ± 8 years, FEV_1 61 ± 27 % of predicted) were recruited from community. All patients had practiced Tai Chi for more than one year and were free of clinically significant coexistent diseases (e.g., cardiac disease, neuromuscular disorders or severe arthritis) that might preclude exercise and had not had an exacerbation of COPD within the preceding month. Patients with cancer or severe obesity were also excluded. The study was approved by the Ethical committee of the first affiliated hospital of Guangzhou Medical University. All participants provided written informed consent to participate.

2.1. Protocol

Each patient visited the laboratory four times with a two-day-interval between visits. At visit 1 patients received a physical examination and we measured spirometry. At visit 2 an incremental treadmill exercise to determine each individual's maximal load was performed. The incremental treadmill exercise protocol consisted of 3 min standing still followed by an increase in the load every three minutes by increasing 0.5 km/h until intolerable dyspnea or exhaustion occurred; dyspnea was not quantified during the incremental test using a Borg or similar score, but patients were encouraged to continue until the limit of tolerability.

Visits 3 and 4 were for the physiologic study of either Tai Chi or constant rate treadmill walking at 60% of maximal load determined at visit 2. Constant load exercise and Tai Chi which consisted of 10 repeated sections with 6 min duration for each section were performed in random order. Participants were asked to exercise on a treadmill for 60 min to match the duration of Tai Chi which is usually last 60 min. A five minute warm up was allowed before Tai Chi. A video of one of the participants undertaking Tai Chi may be viewed at online supplement (http://183.63.72.215:88/play/index.html).

2.2. Measurements

The same measurements were made before, during and after both Tai Chi and constant rate exercise as follows. A long (5 m) lead suspended from a pulley that was free to move at the level of the laboratory ceiling was used to permit recording of EMGdi and esophageal pressure during Tai Chi exercise without limiting the participants movement (Please see online video).

Inspiratory capacity (IC) was performed before and immediately after exercise to quantify dynamic hyperinflation (Guenette et al., 2012). Oxygen uptake (VO_2), carbon dioxide production (VCO_2), minute ventilation (V_E), respiratory rate, heart rate and SpO_2 were continually measured with a facemask and finger probe connected to a portable metabolic 'cart' worn by patient (K4b^2, COSMED,Italy) during exercise. Respiratory rate and VO_2 during exercise were considered the average of 3 min before the end of exercise and compared with 3 min during rest. Since Tai Chi requires breathing control we did not feel it appropriate to perform interval measures of IC or to ask participants to vocalise to record Borg dyspnea or leg scores, and therefore did not undertake these during treadmill exercise either.

Diaphragm electromyography (EMGdi) was recorded using a combined multipair esophageal electrode catheter with an esophageal balloon mounted on it passed pernasally, as previously described(Luo et al., 2009; Jensen et al., 2011). The EMG signals were bandpass filtered between 20 and 1000 Hz and amplified (Bioamplifier Model RA-8, Yinghui Guangzhou, China). The esophageal balloon was filled with 0.5 ml air and connected to a pressure transducer (DP15, Validyne Corp., Northrige, CA, USA).

Quadriceps fatigue was evaluated by measuring the unpotentiated quadriceps twitch tension (TwQ) using the similar technique previously described (Polkey et al., 1996; Hamnegard et al., 2004). The participants were studied supine with the knee flexed at 90° over the end of the chair. An inextensible strap was placed around the ankle and connected to a strain gauge (strain stall range 0–100 kg) mounted to the back of the chair so that the strap ran perpendicular to the ankle and gauge. A 43-mm figure-of-eight coil powered by a Magstim 200 stimulator (Magstim Company Limited, Whitland, Dyfed, Wales) was used to stimulate the right femoral nerve; a minimum of 5 stimulations at 100% of stimulator output were given and the mean TwQ used for analysis. The unpotentiated TwQ was measured before, 20 min and 60 min after both constant load treadmill and Tai Chi exercise.

2.3. Statistical analysis

Data were presented as mean ± SD. A two way repeated measures ANOVA and a paired *t*-test were used to assess the differences between Tai Chi and treadmill exercise.

Table 1
characteristic of patients with COPD.

Subject no.	Sex	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)	$FEV_{1\ (litre)}$	$FEV_{1\ (\%\ pred)}$	VC (litre)	FEV_1/VC (%)	IRV (litre)	IC (litre)	Smoking (years)
1	M	62	64.0	162	24.4	2.88	108	4.80	60.0	3.12	3.62	30
2	M	63	67.0	165	24.6	2.24	85	3.82	58.6	1.46	2.24	40
3	M	63	83.6	170	28.9	1.54	54	3.76	41.0	1.19	2.82	40
4	M	57	67.5	169	23.6	1.31	44	3.25	40.3	1.52	1.56	30
5	M	66	65.0	163	24.5	1.10	44	2.31	47.6	0.84	1.81	10
6	M	71	71.0	161	27.4	1.52	67	2.78	54.7	1.48	2.01	30
7	F	54	59.0	157	23.9	1.45	66	2.70	53.7	1.01	2.41	0
8	M	67	57.0	165	20.9	0.59	22	2.72	21.7	0.57	1.40	40
9	M	46	76.0	168	26.9	2.02	60	3.90	51.8	1.17	2.47	30
10	M	72	56.0	163	21.1	2.36	97	3.73	63.3	0.53	2.34	30
11	M	57	56.0	159	22.2	0.76	28	3.33	22.8	0.56	1.61	30
Mean	¡ ¡	62	65.6	164	24.4	1.62	61	3.37	46.9	1.22	2.21	28
SD	¡ ¡	8	8.8	4	2.5	0.70	27	0.72	14.2	0.73	0.64	13