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The effect of different exercise modalities on dyspnea and leg fatigue in healthy subjects

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ABSTRACT

Background: This study documents the impact of different exercise modalities on dyspnea and leg fatigue during equivalent cardiopulmonary stress in healthy subjects.
Methodology: Following a familiarization, 20 subjects (age 21–44 years; 8 males) performed six 5-min exercise tests, randomized among: 2 steep slope treadmill tests (25% grade), 2 lesser slope treadmill tests (12% grade) and 2 bicycle tests on 3 separate days. Subjects reported either dyspnea or leg fatigue during each test. Oxygen consumption ($\dot{V}O_2$), ventilation ($\dot{V}_E$), respiratory rate (f_R) and heart rate (HR) were measured during each test.
Results: $\dot{V}O_2$, $\dot{V}_E$, HR, dyspnea and leg fatigue were not significantly different among the three exercise conditions ($p > 0.05$).
Conclusion: These findings indicate that at equivalent levels of cardiopulmonary stress reflected by similar levels of $\dot{V}O_2$ and heart rate, the perceived level of exertional dyspnea is not influenced by different patterns of neuromuscular activity. Similarly, the intensity of leg fatigue primarily reflects whole body work and is independent of different patterns of neuromuscular activity.

1. Introduction

Dyspnea on exertion is common in both healthy subjects and patients with heart and lung disease, but a key difference is the level of activity at which this sensation becomes troublesome (Grazzini et al., 2005; West et al., 2010). In patients with heart and lung disease, dyspnea can become a fearful experience (O'Driscoll et al., 1999; Parshall et al., 2012) and is a major factor promoting exercise avoidance in these populations (Meek and Lareau, 2003; O'Donnell et al., 1997). In addition to their cardiac and/or ventilatory failure such patients often experience peripheral muscle dysfunction secondary to systemic inflammation (Agustí et al., 2002; Bernard et al., 1998; Casaburi, 2001) and this presumably contributes to their other major exercise symptom, a sense of leg fatigue. Together these perceptions are regarded as the primary symptoms limiting exercise in both healthy individuals (Saltin and Calbet, 2006; Wagner, 1996) and patients with chronic obstructive pulmonary disease – COPD (Kinsman et al., 1983).

Although a number of options are now available for the palliation of dyspnea, none is highly effective and much individual variability in responses is noted; this partly reflects our limited understanding of dyspnea (West et al., 2010; Parshall et al., 2012). These days, one of the primary therapeutic approaches to the management of this symptom is exercise-based pulmonary rehabilitation that focuses on improving peripheral muscle function and thereby managing the symptomatology, functional capacity and health-related quality of life (Nici et al., 2006; Nici and ZuWallack, 2014). There is clear evidence that such an approach reduces exertional dyspnea and while there is a view that this is mediated though psychological desensitization and a muscle training-related reduction in ventilatory drive (Porszasz et al., 2005), there remains the possibility that afferent feedback from conditioned muscles may ameliorate dyspnea by more directly influencing the central neural processes that give rise to this sensation. Recent findings have suggested that afferent feedback from fatigued lower limbs can independently influence dyspnea perception (Grippo et al., 2010; Sharma et al., 2015).

The purpose of the present study was to explore the potential modulating effect of afferent feedback from exercising limbs on dyspnea perception. To achieve this, 20 healthy subjects recruited from the general population, performed three different exercise protocols on bicycle ergometer and treadmill each on two

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occasions while reporting either exertional dyspnea or leg fatigue. We hypothesized that for a given level of cardiopulmonary stress, bicycle exercise (which involves greater lower limb muscle activity) would be associated with a greater intensity of exertional dyspnea (and leg fatigue) compared with treadmill exercise. We further hypothesized that more forceful leg muscle contractions (steep treadmill) would induce greater dyspnea than more frequent ones (fast treadmill).

The preliminary findings of this study have been presented at an American Thoracic Society International Conference and published as an abstract in the supplementary issue of the American Journal of Respiratory and Critical Care Medicine (Sharma et al., 2012).

2. Methods

2.1. Subjects

The study was carried out on 20 healthy volunteers (Table 1) recruited from the Griffith University staff/student population following ethical approval by Griffith University Human Research Ethics Committee. Subjects were screened using the AHA/ACSM Health/Fitness Preparticipation Screening Questionnaire (ACSM, 2013) to meet the established criteria for undertaking a submaximal exercise test without medical supervision. Resting blood pressure and forced spirometry (Medikro Spirostar 2000, Medikro Oy, Kuopio, Finland) were performed according to standard guidelines (Miller et al., 2005) as a part of the screening procedure. All subjects had resting blood pressure and lung function values within their predicted normal range (Table 1).

The study involved four laboratory sessions on four different days with at least one visit per week and no studies undertaken on consecutive days. The baseline characteristics of subjects are detailed in Table 1.

2.2. Aerobic exercise paradigms

The study required participants to undertake three different aerobic exercise protocols, each lasting 5 min; there were two treadmill protocols and one bicycle ergometer protocol. All exercise bouts were designed to produce equivalent levels of cardiopulmonary stress, and each test was performed twice with reporting of either exertional dyspnea or leg fatigue. For each individual we used prediction equations (ACSM, 2013), to determine our three exercise protocols that would yield equivalent workload intensities as follows: (a) A treadmill test at a relatively slow walking speed (~4 kph) with a steep (~25%) slope (STM) (b) A treadmill test at a relatively fast walking speed (~7 kph) with a less steep (~12%) slope (FTM) and (c) A bicycle test at a constant workload (Bike).

Table 1
General characteristics of participants ($n = 20$).

Characteristics	Male	Female
Age range (years)	21–42	22–44
Mean age (years)	30.8 ± 8.9	33.9 ± 7.2
Number of participants	12 (60%)	8 (40%)
Systolic blood pressure (mmHg)	123 ± 10	121 ± 10
Diastolic blood pressure (mmHg)	72 ± 15	75 ± 8
Height (cm)	178.3 ± 7.1	171.2 ± 4.0
$\dot{V}O_2$ max (ml/kg/min)	44.7 ± 5.2	34.7 ± 5.8
$\dot{V}O_2$ max (% predicted)	104 ± 10	98 ± 15
BMI (kg/m^2)	24.3 ± 2.0	22.4 ± 3.6
FEV_1 (% predicted)	98 ± 11	102 ± 13
FVC (% predicted)	102 ± 18	104 ± 12

Values are expressed as mean ± SD.
BMI – body mass index, FEV_1 – forced expiratory volume in 1 s, FVC – forced vital capacity.
$\dot{V}O_2$ max – maximal oxygen consumption estimated from Jackson et al. (1990).

For each participant, these protocols were "fine-tuned" during an initial familiarization visit to the laboratory to adjust the treadmill settings to match the measured peak $\dot{V}O_2$ attained during cycle ergometry.

2.3. Cardiorespiratory measures

During all exercise tests, subjects breathed through a facemask connected to a metabolic system (Quark, Cosmed Srl Italy) to record the breath-by-breath measures of tidal volume (V_T), respiratory frequency (f_R), pulmonary ventilation ($\dot{V}_E$) and heart rate (HR) (via an integrated Polar monitor). ECG and pulse oximetry (SpO_2) were monitored throughout each exercise test (Prizm 5 patient monitor, Charmcare Co. Ltd, Seoul, Korea); the CM5 ECG configuration was used to optimize the detection of any exercise related rhythm disturbances.

2.4. Rating of dyspnea

Before each exercise test, subjects were asked to rate either the intensity of their exertional dyspnea or leg fatigue. For dyspnea, subjects were asked to relate to their common experience of "getting short of breath (SOB)" while exercising; running to catch a bus or quickly climbing several flights of stairs were provided as examples of situations typically giving rise to this feeling. Subjects were advised to self-monitor their intensity of dyspnea throughout the exercise test and to rate this continuously (Harty et al., 1993) using a previously validated 0–10 numeric scale (Morris et al., 2007). Subjects were advised that a rating of "0" meant that they felt no breathing discomfort such as they would experience at rest and that a rating of "10" meant a level of discomfort which would cause them to stop or lower their exercise intensity in order to gain relief from their shortness of breath. These ratings were made using a computer based system with a monitor mounted in front of either the bicycle or treadmill. The number displaced on the monitor was controlled by a clicker attached at the right hand side of the handbars/handrail during exercise. The displayed number changed by 0.5 unit with each click and subjects had the option of increasing or decreasing the value according the level of breathing discomfort they experienced during the exercise. During these tests, subjects were asked to focus solely on their shortness of breath.

2.5. Rating of leg fatigue

For leg fatigue, subjects were asked to relate to their common experience of leg discomfort while exercising; walking or cycling up a steep slope were provided as examples of situations typically giving rise to this feeling. Ratings of perceived leg fatigue were made throughout exercise using a 0–10 scale as described for dyspnea (see above). Subjects were advised that a rating of "0" meant that they felt no discomfort in their legs such as they would experience at rest and that a rating of "10" meant a level of discomfort which would cause them to stop or lower their exercise intensity in order to gain relief from their tiredness or fatigue in their legs. During these tests, subjects were asked to focus solely on their leg discomfort; again they were able to increase or decrease ratings as described above for dyspnea.

2.6. Experimental protocol

2.6.1. Visit 1 (familiarization visit)

The first visit involved familiarizing the participant with the laboratory environment and the study procedures. During this visit, informed written consent was obtained and height, weight, resting blood pressure and forced spirometry measurements were performed to enable risk stratification screening. A record of each