Response to Moderate and Vigorous Aerobic/Resistance Exercise in a Woman With Long-COVID

Jeffery Schlicht, PhD[1], Paul M. Gallo, EdD, FACSM-CEP[2,3]

PATIENT BACKGROUND

Patient X is a 44-year-old white woman diagnosed in November 2020 with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a novel β-coronavirus, which causes coronavirus disease 2019 (COVID-19) (Table 1) (1). Her symptoms persisted for >6 months postinfection leading to a diagnosis of long-COVID (2). Prior to testing positive for COVID-19 she had been participating in ≤2 hours of moderate to vigorous intensity treadmill, over-ground, and ergometer-based exercise 5 to 6 days per week. She did not perform resistance training. Her medical history and progression from COVID-19 to long-COVID are illustrated in Figures 1 and 2, respectively.

Shortly after becoming infected with COVID-19, and continuing for the ensuing 2 weeks, she self-administered over-the-counter medications, including 600 mg of guaifenesin twice daily, 500 mg of acetaminophen 4 times daily, and cough drops. Despite these therapies, she continued to experience symptoms of dyspnea and fatigue, which were clinically diagnosed in December 2021. Her primary care physician recommended walking as tolerated and prescribed no other therapy. Eight months after testing positive for COVID-19 and immediately prior to this study, her exercise routine included treadmill walking at self-perceived low to moderate intensity (3 to 4 days per week for 30 to 45 minutes per day), and occasional (<1 day per week) resistance training (1 set of 20 repetitions for 3 to 5 arm exercises).

Protocol Overview

This study was approved by the Norwalk Community College Institutional Review Board. Voluntary written informed consent was provided prior to participation.

All testing occurred during a single 4-hour session that included a graded exercise test (GXT), bouts of moderate and vigorous intensity treadmill walking, a 1-repetition maximum (1RM) test, and multiple sets of seated leg press (Figure 3). The participant fasted 4 hours prior to testing and refrained from pretest exercise for 24 hours. Detailed descriptions of testing protocols and equipment specifications are available in the Supplemental Material. Test terminating criteria included achieving age-predicted heart rate (HR) maximum, peripheral oxygen saturation (Spo_2) ≤88%, Modified Borg Dyspnea Scale ≥5/10 (severe dyspnea), and/or request to stop.

TABLE 1. Clinical characteristics.

Variable	Value
Race and Gender	White Woman
Age, years	44
Height, m	1.73
Weight, kg	73.0
Body Mass Index, $kg \cdot m^{-2}$	24.4

Aerobic Exercise Testing

Habitual walking speed, determined by the 10-Meter Walking Test, established the constant GXT treadmill speed of 1.34 $m \cdot sec^{-1}$ (3 mph). Final stage GXT workload occurred at 20% grade coinciding with a peak HR of 170 $b \cdot min^{-1}$. Peak exercise oxygen uptake (Vo_2) was estimated at 40.5 $mL \cdot kg^{-1} \cdot min^{-1}$ (11.6 METs). Steady state HR was

[1]Department of Health Promotion and Exercise Sciences, Western Connecticut State University, Danbury, CT 06810 USA
[2]Department of Exercise Science and Wellness, Norwalk Community College, Norwalk, CT 06854 USA
[3]Department of Biobehavioral Sciences, Teachers College Columbia University, New York, NY 10027 USA

Address for correspondence: Paul M. Gallo, EdD, FACSM, ACSM-CEP, Exercise Science and Wellness Department, Norwalk Community College, 188 Richards Avenue, Norwalk, CT 06854; (203) 857 7194; e-mail: pgallo@norwalk.edu.

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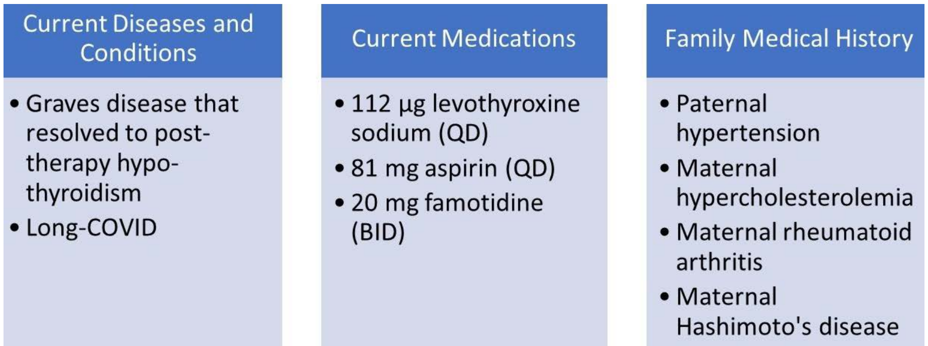

FIGURE 1. Medical history.

computed using the average of minutes 3 to 6 for each 6-minute walking test (3).

Target HR levels set for 60% and 80% peak HR walking tests were 134 b·min^{-1} and 152 b·min^{-1}, respectively, corresponding to treadmill grades of 10% and 12%, respectively. The treadmill belt speed (1.34 m·sec^{-1}; 3 mph) used for the GXT was also used for submaximal walking tests.

Strength Testing

The seated leg press was used to evaluate 1RM load. Lifting intensities for 8-repetition testing were set at 50%, 60%, 70%, and 80% 1RM.

RESULTS

Total exercise testing time was 26 minutes (23 minutes of walking and 3 minutes of leg press) over approximately 90 minutes interspersed with rest. All exercise intensities and modalities were tolerated without reporting severe dyspnea or Spo_2 desaturation (Table 2 and Figure 4).

Aerobic Exercise Testing

Steady state HRs (mean ± SD) during 60% and 80% walk tests were 153 ± 2 b·min^{-1} and 163 ± 3 b·min^{-1}, respectively. During the 60% peak HR test, HR was higher than expected and within the range of moderate to vigorous intensity. The HR during the 80% peak HR walk test was also higher than expected, although remaining within the vigorous intensity domain.

Strength Testing

The participant achieved a 1RM of 155 lbs (70.5 kg), which was confirmed with an OMNI-resistance exercise scale score of 10/10.

Dyspnea

Dyspnea increased with intensity during each treadmill test, peaking at 4/10 (range: 0.5 to 4) during the final 2 stages (18% and 20% grade) of GXT. Her dyspnea range was 1/10 to 2/10 and 1/10 to 3/10 during 60% and 80% walk testing, respectively. Dyspnea also increased with intensity across the 4 %1RM leg press sets, reaching a peak of 3/10 (range 0.5 to 3).

Peripheral Blood Oxygen Saturation

The Spo_2 response to GXT was stable, remaining within a range of 97% to 98%. During the 60% walk test, Spo_2 was 94% to 96%. Similarly, Spo_2 was 95% to 97% during the 80% walk test. Throughout %1RM testing Spo_2 was 98% to 99%.

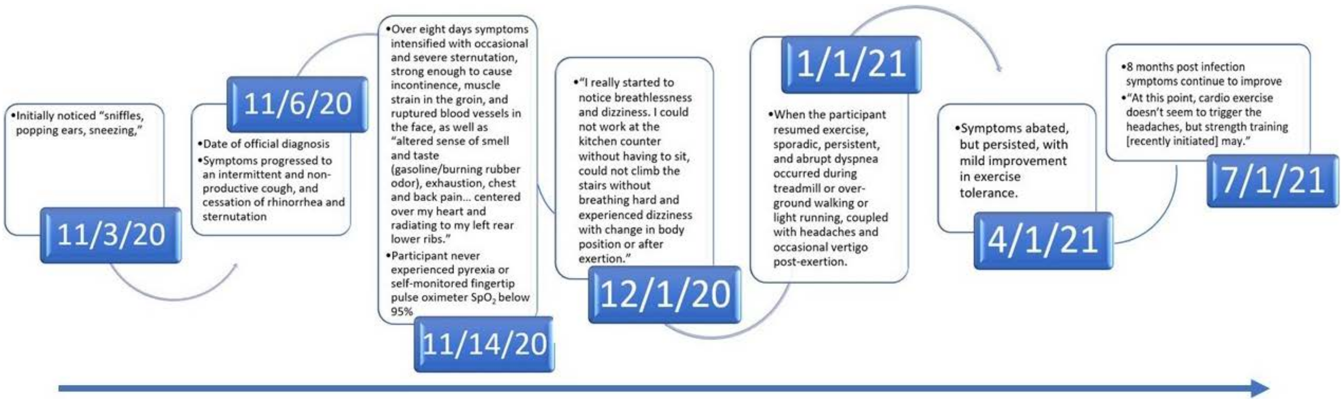

FIGURE 2. COVID-19 symptomology progression. Self-recorded historical account of illness.

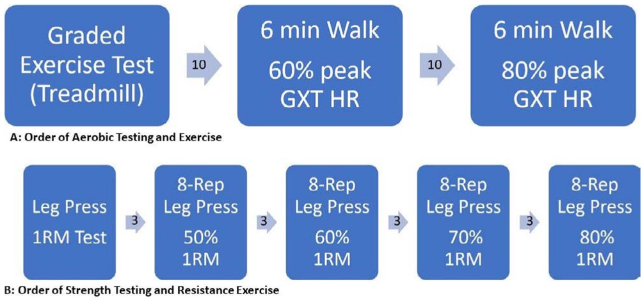

FIGURE 3. Exercise testing progression. Numbers within arrows indicate rest time (min) between tests.

TABLE 2. Dyspnea and peripheral blood oxygenation during rest and exercise.

Variable	Value
Resting Values	
Seated Heart Rate, b·min^{-1}	79
Seated Blood Pressure, mm Hg	120/74
Seated Spo_2, %	98
Seated MBDS (1-10, scale)	0; Nothing at all
Peak Exercise Values	
GXT Heart Rate, b·min^{-1}	170
GXT Workload, speed, m·sec^{-1}; grade, %	1.34; 20
GXT MBDS (1-10, scale)	4; Somewhat severe
GXT Spo_2, %	97 (Minutes 4 & 5)
Leg Press, 1RM	150 lbs. (70 kg)
Submaximal Exercise Values	
60% Heart Rate, mean ± SD, b·min^{-1}[a]	153 ± 2
60% Constant Workload, speed, m·sec^{-1}; grade, %	1.34; 10
80% Heart Rate, mean ± SD, b·min^{-1}	163 ± 3
80% Constant Workload, speed, m·sec^{-1}; grade, %	1.34; 12
50% 1RM Load[b]	75 lbs (34.1 kg)
60% 1RM Load	90 lbs (40.9 kg)
70% 1RM Load	110 lbs (50 kg)
80% 1RM Load	125 lbs (56.8 kg)

1RM = 1 repetition maximum; GXT = graded exercise test; MBDS = Modified Borg Dyspnea Scale; Spo_2 = peripheral oxygen saturation

[a]Two 6-minute treadmill walking bouts were performed at moderate- and vigorous-intensity (60% and 80% peak GXT heart rate, respectively) with heart rate reported for minutes 3 to 6 (mean ± SD)

[b]Leg press testing was performed for a single set of 8 repetitions set at 50%, 60%, 70%, and 80% of 1RM. For submaximal exercise values of dyspnea and Spo_2, see Figure 4

DISCUSSION

Epidemiology and Etiology

Over 500 million individuals worldwide have been infected with COVID-19 (1). Some individuals continue to demonstrate symptoms more than 12 weeks following initial infection resulting in a subsequent diagnosis of *long-COVID* (2,4). Dyspnea and fatigue are the most commonly reported symptoms, but others may also include anxiety, depression, dizziness, headaches, impaired cognition, and nausea (2,5,6).

Diagnosis and Treatment

There are no set diagnostic criteria for predicting long-COVID (1). There are also no proven pharmacologic therapies for curing long-COVID, resulting in treatment plans aimed at managing symptom severity (5). This has led to the Centers for Medicare and Medicaid Services (CMS) approving pulmonary rehabilitation (PR) as a reimbursable therapy for managing signs and symptoms of long-COVID (6,7).

While theoretical rationale (8) and preliminary research (9) suggest PR may be effective for long-COVID management, there is no standardized exercise programming for these specific patients (10,11). How these patients respond to various intensities and types of exercise is unknown (12). In this case study, we assessed symptom severity and physiological responses across a range of intensities during aerobic and resistance exercises that are typically included as part of an individualized PR exercise prescription.

CLINICAL IMPLICATIONS

The results of this case study demonstrate neither aerobic nor resistance exercise performed at moderate or vigorous intensities provoked severe dyspnea or Spo_2 desaturation in a woman with long-COVID, a condition prone to unpredictable bouts of breathlessness. Cardiovascular responses to all exercise testing also remained within normal limits to collectively suggest the use of PR individualized exercise training for this population is safe (4,6,7,10,12).

When comparing the protocol used in this case study with that typically administered in PR, similarities include exercise type, duration, and order. The length of a typical PR session lasts 60 to 90 minutes and involves multiple transitions across exercise types and modalities (13). The most notable difference between the exercise protocol in our study

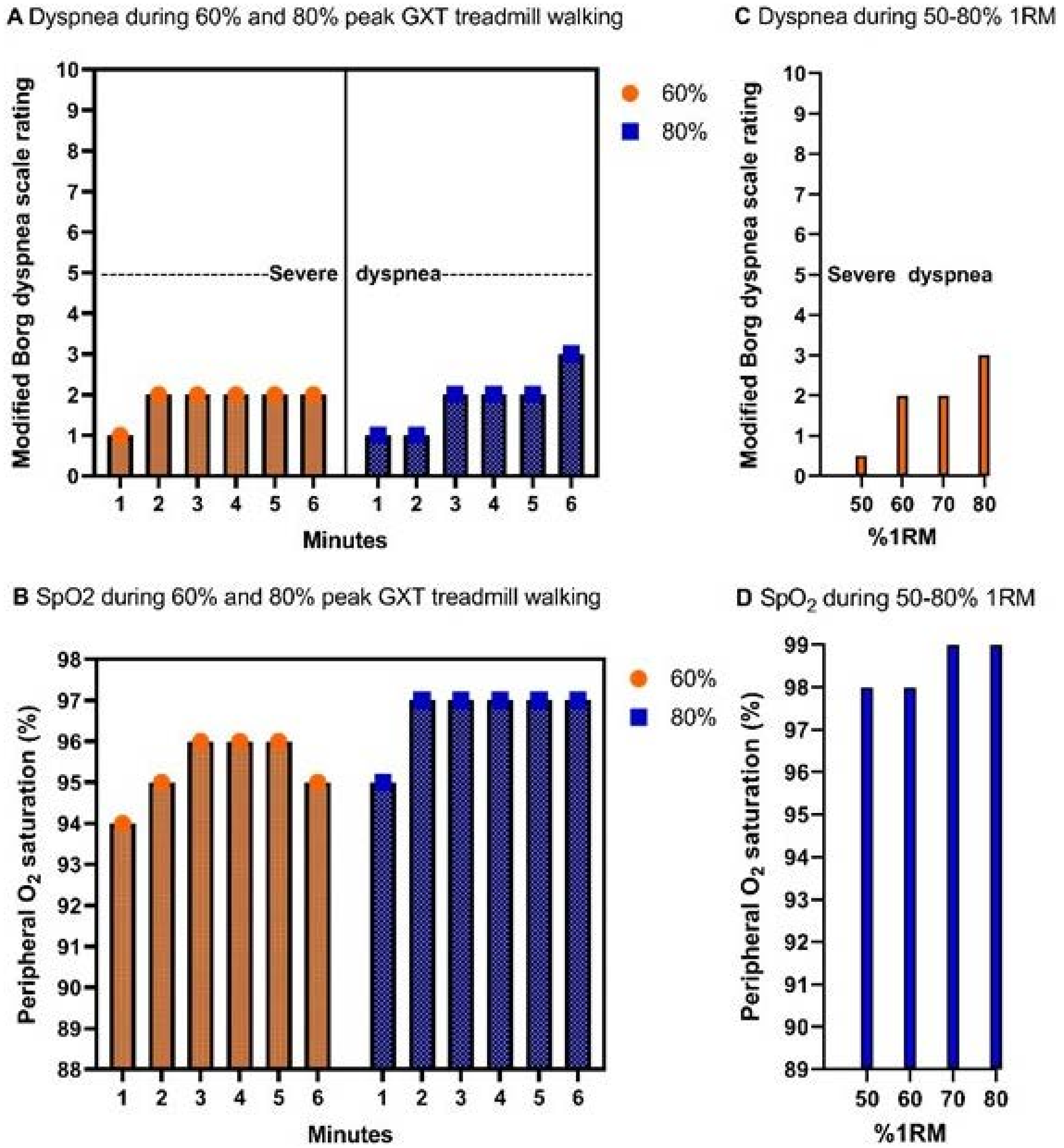

FIGURE 4. Dyspnea and Spo_2 during submaximal aerobic and anaerobic exercise. Panels A and B show dyspnea and peripheral oxygen saturation during 6-minute treadmill walking tests performed at workloads equivalent to 60% and 80% of her peak exercise heart rate. Panels C and D show dyspnea and peripheral oxygen saturation responses during leg press tests set at 50, 60, 70, and 80% 1 repetition maximum.

compared with routine PR sessions is the higher levels of intensity. The estimated peak Vo_2 in the present case placed the individual within the 90th percentile of normative data (11), making it likely that cardiorespiratory fitness of this level is higher than typically observed in patients with long-COVID (10). Lower fitness levels may result in exacerbation of symptoms during or following vigorous intensity exercise. However, a recent literature review suggests that individuals with long-COVID may demonstrate higher fitness levels than clinical PR populations (10). Therefore, clinical exercise physiologists may need to design individual exercise prescriptions using higher initial intensities than typically administered in PR for select patients (6,10,12).

Aerobic Exercise Response

Self-reported dyspnea did not coincide with Spo_2 desaturation in this study. This may be explained by the known weak to moderate relationship between Spo_2 and arterial o_2 saturation (14). Pulmonary dysfunction that would normally lead to o_2 desaturation may also not be the cause of long-COVID dyspnea. Therefore, it is possible Spo_2 may not be a reliable indicator of dyspnea severity in this population (14).

Psychogenic factors such as anticipation of vigorous intensity or fear of dyspnea onset may cause hyperventilation, leading to a sense of increased breathlessness (15). Increased dyspnea during latter phases of aerobic testing could be a result of acid-base dysregulation and accumulated metabolic by-products that trigger respiratory compensation and breathlessness (3). These respiratory responses may be self-interpreted as extreme in deconditioned long-COVID patients who have not recently participated in vigorous intensity exercise, thereby resulting in uncomfortable, but clinically benign high dyspnea levels.

Resistance Exercise Response

Although we did not observe any clinically significant differences in dyspnea between aerobic and resistance exercises in this study, the lower gross accumulation of metabolic by-products during intermittent resistance training may lower the likelihood of severe dyspneic responses (16). Discontinuous exercise may also be better tolerated in long-COVID patients who exhibit dyspnea coupled with severe physical deconditioning, leading the clinical exercise physiologist to recommend initiating resistance exercise earlier than typical during PR participation (16,17). Upper body resistance training may be particularly beneficial in patients where pulmonary dysfunction has been clinically evaluated and identified is the key concern since these exercises have been shown to improve breathing mechanics and exercise capacity (17).

Future research should include pulmonary function testing before and after cardiopulmonary exercise testing to clarify more precise physiologic mechanisms that may lead to abnormal Spo_2 and dyspneic responses in certain long-COVID patients but not others. Randomized controlled trials of exercise interventions in this cohort are also needed to develop guideline-directed aerobic and resistance exercise recommendations for use in PR as a management tool for long-COVID.

SUMMARY

In this case study we described a woman experiencing long-COVID who completed a range of moderate to vigorous intensity aerobic and resistance exercises. She exhibited a typical rise in dyspnea severity relative to work performed and without Spo_2 desaturation. In order to maximize therapeutic gains while minimizing the potential for symptom exacerbation, clinical exercise physiologists should use GXT as part of the baseline evaluation process in order to optimize the development of the individualized exercise prescription for long-COVID patients participating in PR.

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