BRIEF REPORT

Relationship and Responsiveness of Three Upper-Limb Tests in Patients with Chronic Obstructive Pulmonary Disease

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ABSTRACT

Purpose: To determine (1) the relationship among three common upper-limb tests for patients with chronic obstructive pulmonary disease (COPD): unsupported upper limb exercise test (UULEX), 6-minute pegboard and ring test (6PBRT), and a muscle-strength test using a hand-held dynamometer; and (2) the responsiveness of these three tests to changes after pulmonary rehabilitation that included a resistance arm-training programme. ***Methods:*** The study was a secondary analysis of a randomized controlled trial (RCT). The UULEX and the 6PBRT were used to measure peak arm exercise capacity and arm function, respectively. A handheld dynamometer was used to measure elbow and shoulder flexion force. We analyzed baseline data for all participants in the RCT, as well as baseline and post-PR data for those who completed 6-week follow-up testing. ***Results:*** 36 patients with COPD (mean forced expiratory volume in 1 second [FEV_1] = 35% [SD 15%] predicted; age 66 [9] y) participated, of whom 13 completed an arm-training programme. The correlations among the test results ranged from 0.41 to 0.81 ($p < 0.0001$). Standardized response means were 1.0 for muscle force of elbow flexion, 1.2 for shoulder flexion, and 1.8 for the 6PBRT and UULEX. ***Conclusions:*** Although the three tests (UULEX, 6PBRT, and muscle-strength test using a hand-held dynamometer) are intended to measure different constructs, they were moderately to highly correlated with one another. The 6PBRT, UULEX, and muscle-strength test were demonstrated to be responsive to the resistance arm-training programme.

Key Words: chronic obstructive pulmonary disease; exercise test; upper limb.

RÉSUMÉ

Objectif : Cette étude visait à déterminer (1) la relation entre trois tests courants des membres supérieurs et la maladie pulmonaire obstructive chronique (MPOC) : test UULEX (test d'élévation d'un membre supérieur), test de l'anneau (6PBRT) et évaluation de la force musculaire à l'aide d'un dynamomètre manuel; et (2) le degré de réactivité au changement de ces trois tests après une réadaptation pulmonaire comprenant un programme d'entraînement en résistance des bras. ***Méthode :*** Cette étude était une analyse secondaire d'un essai clinique randomisé (ECR). Le test UULEX et le 6PBRT ont été utilisés pour mesurer la capacité maximale d'exercice et la fonction maximale du bras, respectivement. Un dynamomètre manuel a été utilisé pour mesurer la force de flexion du coude et de l'épaule. Nous avons analysé les données de base de tous les patients qui ont participé à l'ECR de même que les données de base et les données après réadaptation pulmonaire des patients qui ont participé à 6 semaines de tests de suivi. ***Résultats :*** 36 patients avec MPOC (moyenne de volume expiratoire maximal [SD] par seconde [$VEMS_1$] = 35 % [15 %] prévus; 66 ans [9]) y ont participé et de ce nombre, 13 ont participé au programme d'entraînement des bras. Les corrélations entre les résultats des tests se chiffraient de 0,41 à 0,81 ($p < 0.0001$). Les moyennes de réponse normalisées ont été de 1,0 pour la force musculaire de flexion du coude, de 1,2 pour la flexion de l'épaule et de 1,8 pour les tests 6PBRT et UULEX. ***Conclusions :*** Bien que ces trois tests (UULEX, 6PBRT et test de force musculaire à l'aide du dynamomètre manuel) visent à mesurer des dimensions différentes, ces mesures étaient modérément ou extrêmement corrélées les unes par rapport aux autres. Le test 6PBRT, le test UULEX et le test de force musculaire ont manifestement été influencés par le programme d'entraînement en résistance des bras.

A wide variety of upper limb (UL) tests have been used in people with chronic obstructive pulmonary disease (COPD).[1] These tests assess different constructs and thus offer multiple choices to clinicians. Some commonly used UL tests are the unsupported upper limb exercise test (UULEX),[2] the 6-minute pegboard and ring

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Contributors: All authors designed the study, collected the data, and analyzed and interpreted the data; drafted or critically revised the article; and approved the final draft.

Competing interests: None declared.

***Physiotherapy Canada* 2013; 65(1);40–43; doi:10.3138/ptc.2011-49**

Table 1 Results of the Arm Muscle Strength and Exercise Tests

	Group; mean score (SD)								
	Control				Intervention				
	6 wk				6 wk				
Test	Pre-training	Post-training	% change	95% CI	Pre-training	Post-training	% change	95% CI	Between-group comparison*
6PBRT, rings moved	306 (46)	335 (66)	9.50	−52.3 to −4.4	298 (86)	357 (94)	19.70	−78.5 to −39.0	$p = 0.032$
UULEX, s	522 (90)	566 (75)	8.50	−68.8 to −13.7	520 (79)	600 (106)	15.30	−106.7 to −52.1	$p = 0.009$
Elbow flexion, lb	48 (9)	47 (12)	–0.80	−2.6 to 3.3	45 (13)	50 (12)	11.40	−8.3 to −2.2	$p = 0.010$
Shoulder flexion, lb†	47 (11)	47 (12)	−0.20	−2.9 to 3.2	41 (12)	46 (11)	10.50	−6.8 to −1.9	$p = 0.029$

*Statistically significant between groups.
† No difference between groups in baseline data except for shoulder flexion force $p = 0.045$.
6PBRT = 6-minute pegboard and ring test; UULEX = unsupported upper limb exercise test.
Source: This table is adapted from Janaudis-Ferreira et al. (2012)[6] with the kind permission of the publisher.

test (6PBRT),[3] and a muscle-strength test using a hand-held dynamometer;[4] these tests measure peak arm exercise capacity, arm function, and muscle strength, respectively. All have been demonstrated to be valid and reliable measures of arm function in patients with COPD.[4,5] When selecting a test, clinicians should consider ease of administration, the target construct, the measurement properties of the tests, and the relationship between the measure of interest and other relevant tests.

The objective of our study was to determine (1) the relationship among three common UL tests for patients with COPD (UULEX, 6PBRT, and muscle-strength test); and (2) the responsiveness of these three tests to changes after pulmonary rehabilitation (PR) that included a resistance arm-training programme.

We hypothesized that since the tests measure similar but not identical constructs, there would be moderate correlations (in the range of 0.25–0.50) among the UULEX, 6PBRT, and muscle-strength test. We also hypothesized that the UULEX, 6PBRT, and muscle-strength test would be highly responsive to PR that included arm training, as represented by standardized response means (SRMs) ≥ 0.8.

METHODS

This study is a secondary analysis of data collected during a randomized controlled trial (RCT) that examined the effects of resistance arm training as part of a PR programme for patients with COPD, which has been described in detail elsewhere.[6] In brief, 36 patients with COPD (19 in the control group; 17 in the intervention group) were included in the study and exercised three times a week for 6 weeks. Participants in the intervention group participated in a resistance arm-training programme using free weights and a multi-station gym (Model #200i, Eurosport Fitness Innovations Inc., Kelowna, BC). The control group underwent sham training, which consisted of flexibility and stretching exercises. The arm-training programme took place concurrently with the PR programme. To achieve our first objective, we analyzed data collected at baseline for all 36 RCT participants; to achieve our second objective, we included data collected both at baseline and after PR completion for participants who completed the resistance arm-training programme ($n = 13$). To facilitate interpretation of these data, we include baseline and post-PR data for the control group ($n = 18$) in Table 1. Specific inclusion and exclusion criteria have been described elsewhere.[6] Ethics approval was obtained from the hospital's ethics board.

Outcome Measures

Unsupported upper limb exercise test

The UULEX was used to measure peak unsupported arm exercise capacity.[2] The UULEX is an incremental test during which the seated participant holds a plastic bar (0.2 kg) and is instructed to lift it through eight levels at a constant cadence of 30 beats per minute, dictated by a metronome. When the maximum height is reached, participants receive a heavier bar. Thereafter, the weight of the bar is increased by 0.5 kg, to a maximum weight of 2 kg, after every minute; the test continues until exhaustion. The outcome of the UULEX is expressed in seconds. No practice test was done before the test.

6-minute pegboard and ring test

The 6PBRT was used to measure arm function.[3] During this test, the participant sits in front of a pegboard and is asked to move as many rings as possible from two lower pegs to two upper pegs, and vice versa, using both hands simultaneously, over a 6-minute period. Participants familiarized themselves with the test procedure by moving several rings before the test. Standardized encouragement was given at 1-minute intervals during the test; the final score is the number of rings moved during the 6-minute period.

Muscle-strength test

Isometric muscle force of elbow and shoulder flexion was measured on the dominant side using a hand-held dynamometer (MicroFET 2; Hoggan, West Jordan, UT). Participants performed up to six trials, with a 1-minute rest between trials; the average of the highest three measures within 5% of one another was used for analysis.

Statistical Analysis

To achieve our first objective, we analyzed baseline data for the 36 participants using Pearson's correlations. The grade system suggested by Lacasse and colleagues was chosen for interpreting the correlation coefficients: coefficients of correlation between 0 and 0.20 were considered unimportant, between 0.21 and 0.35 weak, between 0.36 and 0.50 moderate, and >0.50 strong.[7] For the second objective, we calculated the SRM by dividing the mean change of the tests by the SD of the change score for the 13 participants who completed the arm-training programme.[8] Values of 0.20, 0.50, and ≥ 0.80 correspond to small, moderate, and large responsiveness respectively.[9] Repeated-measures analysis of variance (ANOVA) was used to evaluate main effects for group vs. time interaction.

RESULTS

Of 36 participants ($FEV_1 = 35\%$ [15%] predicted; age 66 [9] y), 13 ($FEV_1 = 37.8\%$ [16.2%] predicted; age 69 [9] y) completed the arm training programme as part of their PR programme. Results of the arm muscle strength and arm exercise tests are summarized in Table 1.

Objective 1: Relationship between the tests

The correlations between elbow flexion strength and (1) shoulder flexion strength, (2) 6PBRT, and (3) UULEX were 0.81, 0.54, and 0.64 respectively ($p < 0.0001$). The correlations between shoulder flexion strength and (1) 6PBRT and (2) UULEX were 0.41 ($p = 0.016$) and 0.56 ($p < 0.0001$) respectively; the correlation between 6PBRT and UULEX was 0.74 ($p < 0.0001$).

Objective 2: Responsiveness of the tests

All test scores improved following the arm-training programme (all ps < 0.003). SRMs for arm training were 1.0 for elbow flexion strength, 1.2 for shoulder flexion strength, and 1.8 for the 6PBRT and UULEX.

DISCUSSION

Our results demonstrate moderate to strong correlations among the muscle-strength test, UULEX, and 6PBRT, as well as the responsiveness of all three tests to a PR programme that included arm training. These findings can be used to guide clinicians' decisions on the appropriate test to quantify impairment or to evaluate the effects of an arm-training programme, as our findings show that the three tests are interrelated and responsive to a resistance arm-training programme.

Although we hypothesized that there would be moderate correlations between the UL tests, most of the correlations were strong ($r \geq 0.54$). One possible explanation for this is that even though the muscle-strength test, UULEX, and 6PBRT are intended to measure different constructs (isometric force, arm function, and peak arm exercise capacity), the muscle activity required to complete them is similar (basically, elbow and shoulder flexion). Moreover, even though each test is intended to measure a specific construct, they may all include components of more than one construct and therefore correlate to each other. For example, the correlation between the strength tests and the UULEX demonstrates that the UULEX involves a strength component, while the correlation between the 6PBRT and the UULEX demonstrates that the 6PBRT involves an endurance component. The correlation between shoulder flexion force and 6PBRT ($r = 0.41$) was smaller than that observed between shoulder flexion force and the UULEX, perhaps because the 6PBRT does not require the same degree of shoulder flexion as the UULEX. The highest correlation was between elbow and shoulder flexion force ($r = 0.81$), which was expected, since both tests measure UL muscle strength. Whether these associations are clinically relevant is difficult to know, as there is little research evidence on what constitutes clinical relevance for correlation.

SRMs were larger for the 6PBRT and UULEX than for the muscle-strength test, which may suggest that these tests are more suitable for evaluating the effects of an arm exercise programme. However, the clinical significance of a difference of 0.6–0.8 in SRMs between the muscle-strength test and the 6PBRT and UULEX is not known. Moreover, differences in percent change scores between groups for the 6PBRT, UULEX, and elbow and shoulder flexion strength were found to be 10.2%, 6.8%, 12.2%, and 10.7% respectively (see Table 1), which indicates that the three tests are able to distinguish differences between control and intervention groups. The changes in the 6PBRT and UULEX for the control group suggest that these tests may be less reproducible than the muscle-strength test; however, the fact that participants did not perform a practice 6PBRT or UULEX test before the study may also account for these changes in the control group. Because our arm-training programme consisted mainly of resistance training, it may be that the 6PBRT and the UULEX would be more responsive for programmes that include arm endurance or task-specific activities.

Although reliability and construct validity (hypothesis testing) have been demonstrated for the UULEX and 6PBRT,[2,3] no study has reported the relationship between these tests. The hand-held dynamometer has been demonstrated to be a reliable and valid instrument for measuring muscle strength in a clinical setting[5] and has good test–retest reliability in people with COPD,[4,5] but no data are available on other psychometric properties. Our study provides information on the measurement properties of three arm exercise tests, which can be used to help clinicians choose the most appropriate test.

LIMITATIONS

Our study has several limitations. First, the sample size used to achieve our second objective was small ($n = 13$). Second, the reliability of the UULEX and the 6PBRT has been reported over a few days, but its stability over a longer period (e.g., 6 weeks) has not been established; however, the fact that the control group did not improve to the same extent as the intervention group suggests that a learning effect was not the main reason for the observed improvement (see Table 1). Finally, the UULEX has a ceiling effect once participants reach the final level and receive the final weight, which may limit the test's ability to measure peak arm exercise capacity; this ceiling effect may affect the strength of the relationships between the UULEX and other tests of upper limb endurance. We did not observe this phenomenon, however, since none of our participants received the heaviest weight while on the last level of the test.

CONCLUSION

Although the three UL tests examined in our study (UULEX, 6PBRT, and muscle-strength test using a hand-held dynamometer) are intended to measure different constructs, we found them to be moderately to highly correlated with one another. In addition, we demonstrated that all three tests are responsive to the resistance arm-training programme used in the intervention study. These findings suggest that unless the goal is to measure a specific construct, any one of the three tests may be sufficient to evaluate some aspects of UL function in people with COPD.

KEY MESSAGES

What is already known on this topic

A wide variety of upper-limb tests have been used in people with COPD. These tests assess different constructs and thus offer multiple choices to clinicians. Some commonly used UL tests are the UULEX, the 6PBRT, and a muscle-strength test using a hand-held dynamometer. Although reliability and construct validity (hypothesis testing) have been demonstrated for these tests, no study has reported the relationship between them.

What this study adds

We found moderate to strong correlations among the muscle-strength test, UULEX, and 6PBRT, as well as demonstrating the responsiveness of all three tests to a pulmonary rehabilitation programme that included arm training. These findings can be used to guide clinicians' decisions on the appropriate test to quantify impairment or to evaluate the effects of an arm-training programme, as we have shown that the three tests are interrelated and are responsive to a resistance arm-training programme.

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