LITERATURE REVIEW

6PBRT and UULEX as an Unsupported Upper Limb test in People with Respiratory and Musculoskeletal disability

Nury Nusdwinurintyas [1], Peggy Sunarjo [1], Clements[1]

[1]Physical Medicine and Rehabilitation Department, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia

ABSTRACT

Upper limb (UL) function is essential for daily activities, yet it is often overlooked in rehabilitation programs for individuals with respiratory and musculoskeletal disabilities. The six-minute pegboard and ring test (6PBRT) and the unsupported upper limb exercise test (UULEX) are two validated tools for assessing UL functional capacity. These tests simulate daily UL movements, measuring endurance, strength, and coordination, particularly in patients with chronic obstructive pulmonary disease (COPD), rheumatoid arthritis, asthma, bronchiectasis, interstitial lung disease, and pulmonary hypertension. Research suggests that UL exercises improve dyspnea, endurance, and activities of daily living (ADLs), supporting their integration into rehabilitation programs. This review explores the methodology, clinical applications, and benefits of 6PBRT and UULEX, highlighting their role in comprehensive patient assessment and functional rehabilitation.

Keyword: upper extremity function, pulmonary rehabilitation, exercise rehabilitation, exercise test, chronic obstructive pulmonary disease, activities of daily living

Correspondence Detail:
Peggy Sunarjo
Physical Medicine and Rehabilitation Department, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia
Email: roswitapeggy@gmail.com

INTRODUCTION

Upper limbs activities, whether supported or unsupported, are common when performing activities of daily living (ADLs), such as eating, bathing, brushing teeth, combing hair, shaving, doing the dishes, or putting groceries on shelves.[1] Katz et all's model of functional assessment focuses on the task individuals perform on a daily basis. Their work is based on the premise that there are six ADLs that are basic; bathing, dressing, toileting, transferring, continence and feeding.[2] Previously, most pulmonary rehabilitation (PR) programs focused on exercising the lower extremities. However, upper-extremity exercise is increasingly recognized as an important component of PR.[3]

Some patient, as well as Chronic Obstructive Pulmonary (COPD), experience a lot of symptoms and activity limitations, including dyspnea, fatigue, and exercise intolerance and often have comorbidities such as cardiovascular diseases, osteoporosis, limb muscle dysfunction, and psychological

disorders, all of which contribute to limited capacity and restricted participation in physical and emotional ADLs, and as a consequence to a poor health-related quality of life (QoL).[4,5] Measurements of upper and lower limbs functional capacity in ADLs are necessary for a comprehensive management of the disease.[6] In fact, upper limbs activities during ADLs often exacerbate dyspnea much sooner than lower limb activities.[4]

There are various types of upper limbs (ULs) exercise tests available for patients with disabilities. One of the tests that mimics ADLs performed by the ULs is the six-minute pegboard and ring (6PBRT) test.[1] The 6PBRT is the most commonly used for assessing the functional capacity of ULs in patients with COPD and was first described by Celli et al. It's also been used to show the efficacy of ULs exercise training programs.[7] Another test to assess functional capacity of the ULs often performed is unsupported upper limb exercise (UULEX) test. It is a standardized symptom-limited incremental test that assesses peak unsupported arm exercise capacity, which makes the test have great clinical application. This test is also valid and reliable in COPD patients. The movements made during these tests reflect the ULs movements during daily tasks.[8]

The purpose of this review is to introduce the use of ULs exercises as a complementary tool to assess functional capacity in people with disabilities such as COPD, rheumatoid arthritis[9], asthma[10], bronchiectasis[11], interstitial lung disease[12], and pulmonary hypertension[13] with the reference values of the healthy individuals.

Functional Capacity

Functional capacity is an individual's capability, under controlled conditions, to perform activities that require physical exertion. Functional capacity is primarily determined by the integrity of the cardiovascular, respiratory and skeletal muscle system. If one or more of these systems are compromised, functional capacity will decline.14,15

Functional Capacity of the Upper Limbs

The functional capacity of ULs is an important component in the execution of ADLs, as their integrity permits the appropriate performance of the ULs functions, which are guided reaching, grip and object handling. The Gold standard assessment for ULs functional capacity is the Arm ergometer, as it can determine the maximum cardiorespiratory responses. Disadvantages include its high cost, the need for periodical maintenance, and the different ULs positioning during the test (with support and shoulders at 90º) from what is adopted during ADLs.[16]

Activity of Daily Living

Activities of daily living (ADLs) is used as an indicator of a person's functional status. It's a term used in healthcare referring to basic and everyday skills.[17,18] There are two classifications of ADLs; the basic ADLs (BADLs) and instrumental ADLs (IADLs). BADLs or physical ADLs are those skills required to manage one's basic physical needs, including personal hygiene or grooming, dressing, toileting, transferring or ambulating, and eating. The IADLs include more complex activities related to the ability to live independently in the community.[17]

6PBRT and UULEX

What They Assess and Methods of Use

Both 6PBRT and UULEX assess unsupported ULs exercise capacity. The 6PBRT specifically measures coordination and isometric ULs function by evaluating elbow and shoulder flexors, while UULEX is a symptom-limited test used to assess the peak exercise capacity, measuring dynamic shoulders flexion endurance above and below shoulder height.[8,19] Both tests are performed by sitting straight and subject's vital sign were recorded before and after test.[20]

In 6PBRT, a table-mounted board is placed in front of the subjects and they're asked to move as many rings as possible from the two lower pegs to the two upper pegs placed 20 centimetres above shoulder level and vice

versa, using both hands simultaneously within 6 minutes (Figure 1.A).[20,21] In UULEX, subjects were seated straight in front of the UULEX chart, then were asked to hold a light plastic bar (weighed 0.2 kg) and move it from their lap to the first level at a constant moving speed of 30 beats per minute (Figure 1.B).

The vertical amplitude of the lift then increased by 0.15 meter every minute until they reach the maximum vertical height, then the bar was replaced by a heavier one (weighed 0.5 kg), continuing the exercise at the highest amplitude level. Every minute, the weight of the bar was progressively increased by 0.5 kg to a maximum weight of 2 kg. In UULEX, subjects were asked to continue the test as long as possible. Termination of this test is conducted by subject's request or if abnormal physiologic responses were observed.[20,22]

A.

B.

Figure 1. A) The six-minute pegboard and ring test. B) The unsupported upper limb exercise.[20]

Tools and Outcome

These tests need several tools to be performed, both needed a straight-back chair and devices for measuring vital signs such as sphygmomanometer, pulse oximeter, etc.[21,22] The 6PBRT needed a pegboard with 10 rings (each weighed 50g), and a timer to count down in 6 minutes period. Then number of rings moved during this period were counted as the outcome.[3,21]

A specific chart is needed to perform UULEX, along with PVC tubes (weighed 0.2, 0.5, 1, 1.5, and 2 kg). Metronome and stopwatch are needed to keep the constant moving speed of 30 bpm and to mark a set of timestamps every 1 minute.22 By the time the test was terminated (either by request or objectively), the performance time were recorded along with the Borg scale, as the outcome.[2,22]

Reference Values (by age and gender)

Studies by Lima et al. have determined the reference values of 6PBRT and UULEX for healthy adults. Conducted in Canadian and Brazilian population, these studies present the results in 10 years interval age groups and divided by genders (Table 1). There is a negative correlation between age and number of rings in 6PBRT, also performance time in UULEX. While gender does no significant effect to the results.[8,20]

Table 1. Reference values in healthy population

Reference Values in Healthy Adults (by sex and age)			
6PBRT in Canadian population		**UULEX in Brazilian population**	
Males (40-49) 403.46 – 518.32 rings (50-59) 381.65 – 543.68 rings (60-69) 374.39 – 446.84 rings (70-79) 239.51 – 550.89 rings (> 80) 268.12 – 374.99 rings Females (40-49) 306.0 – 686.0 rings (50-59) 298.0 – 640.0 rings (60-69) 296.0 – 526.0 rings (70-79) 264.0 – 500.0 rings (> 80) 234.0 – 418.0 rings	Lima et al. (2020)	Male (31-40) 13.19 – 15.00 minute (41-50) 10.32 – 15.00 minute (51-60) 9.00 – 15.00 minute (61-70) 9.00 – 13.20 minute (71-80) 8.17 – 13.51 minute Females (31-40) 12.20 – 15.00 minute (41-50) 12.15 – 15.00 minute (51-60) 9.48 – 15.00 minute (61-70) 9.36 – 13.20 minute (71-80) 9.01 – 13.51 minute	Lima et al. (2020)

DISCUSSION

Initially, the standard exercise testing is based on lower extremities exercises, such as treadmill, cycle ergometry, or step test. However, physical performance is affected not only during walking or stair climbing but also during simple ADLs that involve the ULs. The mechanical effects of arm elevation can already exert the symptom of dyspnea without involvements of the lower extremities.[23,24] Exercising ULs muscles lead to increase in metabolic demand, and eventually increase the respiratory and circulatory workload. Variables such as age and gender will also contribute to the exercise performance.[25] The muscles responsible for arm positioning and postural functions, are sometimes recruited to perform the accessory ventilator function. Hence, individuals with respiratory dysfunctions will present changes in ULs functioning as the muscles in the upper part of the trunk ceases to act only for ventilation purposes.[16] As the ULs exercises were found to be an easy to perform, simple and inexpensive test, also with several studies measuring their validity, the 6PBRT and UULEX have been frequently used in patient with COPD.[24]

We found a Cochrane article reviewing comparison of the outcomes on combined upper limb exercise training (ULET) and lower limb exercise training (LLET) versus LLET alone in patient with stable COPD.

The ULETs performed here are including 6PBRT and UULEX. The article measured two types of outcomes from 12 related studies. Primary outcomes are the symptoms of dyspnea and health-related quality of life. Secondary outcomes including peak upper limb exercise capacity (both supported and unsupported), endurance upper limb exercise capacity (both supported and unsupported), upper limb strength, respiratory muscle strength, physical activity level, ADL function, psychological status, and healthcare utilization. There's a significant improvement when ULET is performed compared to no intervention at all on outcome such as symptoms of dyspnea, endurance upper limb exercise capacity, activities of daily living, and healthcare utilization.

They also found a significant improvement in unsupported endurance ULs exercise capacity in combined ULET and LLET group. In contrast, when combined ULET and LLET is compared to LLET alone, there's no significant difference between groups in symptoms of dyspnea, health-related quality of life, peak ULs exercise both supported and unsupported, supported endurance ULs exercise capacity, ULs strength, and activity of daily living. There was no data about physical activity level in comparison

between combined ULET and LLET with LLET alone.[26]

Studies related to this topic is relatively limited, but a few studies provided inconsistent results with the Cochrane review. A study by Elmorsy et al. shows a significant improvement in health-related quality of life in both ULET alone and ULET combined LLET group. They also support the finding of improvements in unsupported ULs exercise capacity, might be due to improved synchronization and coordination of accessory muscle action during unsupported arm activity.[27] Matsunaga et al. also stated differently, showing a significant improvement in health-related quality of life on combined ULET and LLET group.[28]

Lately, the ULs exercises are starting to gain more attention, not only in COPD patient. For example, in Rheumatoid Arthritis (RA). Although isokinetic dynamometer has been a gold standard method for evaluating muscle strength and proprioception (Stark et al.2011), UULEX has also been validated by Cetin et al. to be used in RA patient. UULEX can be performed in a sitting position, is a mild to difficult test and can be used for all age.[9,29]

6PBRT was recently been evaluated to assess functional ULs exercise capacity in patient with Asthma, and it's shown that 6PBRT is useful for determining which patients should be referred to pulmonary rehabilitation program in order to increase their arm performance and decrease symptoms related to arm-based tasks.[10] Similar findings are observed in patient with bronchiectasis. The 6PBRT is useful to predict ADLs performance, allowing early detection of ULs functional capacity impairment, therefore will be important for monitoring the pulmonary rehabilitation program.[11] UULEX was used to measure ULs functional exercise capacity in patient with interstitial lung disease, the results are similar to those with COPD, suggesting that similar mechanism of ULs exercise limitation may exist in patients with the disease. Therefore, UULEX may also be useful to pulmonary rehabilitation in individuals with interstitial lung disease.[12] In patient with pulmonary arterial hypertension (PAH), the lower limbs exercise treatments are more frequent. However, Kahraman et al. found that the ULs exercise capacity, which was measured by 6PBRT, was also decreased as PAG severity increased, giving the conclusions that UL exercise capacity should also be taken into consideration.[13]

In conclusion, 6PBRT and UULEX are valid, easy to perform, simple and inexpensive tests to measure the upper limb exercise capability. They have been frequently used in patient with COPD, and with the similar mechanism of ULs exercise limitations, 6PBRT and UULEX are also useful for patients with rheumatoid arthritis, asthma, bronchiectasis, interstitial lung disease, and pulmonary hypertension. Both tests are recommended to be used in clinical practice.

REFERENCES

1. Lima VP, Almeida FD, Janaudis-Ferreira T, Carmona B, Ribeiro-Samora GA, Velloso M. Reference values for the six-minute pegboard and ring test in healthy adults in Brazil. Jornal Brasileiro de Pneumologia. 2018 May;44(3):190–4.
2. LEIDY NK. Functional Status and the Forward Progress of Merry-Go-Rounds. Nursing Research. 1994 Jul;43(4):196???202.
3. Takeda K, Kawasaki Y, Yoshida K, Nishida Y, Harada T, Yamaguchi K, et al. The 6-minute pegboard and ring test is correlated with upper extremity activity of daily living in chronic obstructive pulmonary disease. International Journal of Chronic Obstructive Pulmonary Disease. 2013 Jul;8:347.
4. Kruapanich C, Tantisuwat A, Thaveeratitham P, Lertmaharit S, Ubolnuar N, Mathiyakom W. Effects of Different Modes of Upper Limb Training in Individuals With Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis. Annals of Rehabilitation Medicine. 2019 Oct 31;43(5):592–614.

5. Bui KL, Nyberg A, Maltais F, Saey D. Functional Tests in Chronic Obstructive Pulmonary Disease, Part 1: Clinical Relevance and Links to the International Classification of Functioning, Disability, and Health. Annals of the American Thoracic Society. 2017 May;14(5):778–84.
6. Bui KL, Nyberg A, Maltais F, Saey D. Functional Tests in Chronic Obstructive Pulmonary Disease, Part 2: Measurement Properties. Annals of the American Thoracic Society. 2017 May;14(5):785–94.
7. Felisberto R, Barros C, Nucci K, Albuquerque AL, Paulin E, Brito C, et al. Is the 6-minute pegboard and ring test valid to evaluate upper limb function in hospitalized patients with acute exacerbation of COPD? International Journal of Chronic Obstructive Pulmonary Disease. 2018 May;Volume 13:1663–73.
8. Lima VP, Velloso M, Pessoa BP, Almeida FD, Ribeiro-Samora GA, Janaudis-Ferreira T. Reference values for the Unsupported Upper Limb Exercise test in healthy adults in Brazil. Jornal Brasileiro de Pneumologia. 2020;46(1).
9. Cetin SY, Basakci Calik B, Ayan A, Cavlak U. Validity and reliability of the unsupported upper-limb exercise test in individuals with rheumatoid arthritis. International Journal of Rheumatic Diseases. 2019 Oct 9;22(11):2025–30.
10. Calik-Kutukcu E, Tekerlek H, Bozdemir-Ozel C, Karaduz BN, Cakmak A, Inal-Ince D, et al. Validity and reliability of 6-minute pegboard and ring test in patients with asthma. Journal of Asthma. 2021 May 31;59(7):1387–95.
11. Cakmak A, Kocaaga E, Sonbahar-Ulu H, Inal-Ince D, Vardar-Yagli N, Calik-Kutukcu E, et al. Upper Extremity Exercise Capacity and Activities of Daily Living in Individuals With Bronchiectasis Versus Healthy Controls. Physical Therapy [Internet]. 2023 Apr 4;103(4):pzad012. Available from: https://pubmed.ncbi.nlm.nih.gov/37086209/
12. Mendes P, Wickerson L, Helm D, Janaudis-Ferreira T, Brooks D, Singer LG, et al. Skeletal muscle atrophy in advanced interstitial lung disease. Respirology. 2015 Jun 17;20(6):953–9.
13. Özcan Kahraman B. Effect of disease severity on upper extremity muscle strength, exercise capacity, and activities of daily living in individuals with pulmonary arterial hypertension. Turk Kardiyoloji Dernegi Arsivi-Archives of the Turkish Society of Cardiology. 2017;45(5):434–40.
14. Arena R, Cahalin LP, Borghi-Silva A, Phillips SA. Improving functional capacity in heart failure: The need for a multifaceted approach. Current Opinion in Cardiology [Internet]. 2014;29(5):467–74. Available from: https://www.mendeley.com/catalogue/722dd65a-f560-37ec-9fb2-03c18af50172/?utm_source=desktop&utm_medium=1.19.8&utm_campaign=open_catalog&userDocumentId=%7Bea528a42-35c4-4690-95e3-da234e030842%7D8
15. Patterson TL, Mausbach BT. Measurement of Functional Capacity: A New Approach to Understanding Functional Differences and Real-world Behavioral Adaptation in Those with Mental Illness. Annual review of clinical psychology [Internet]. 2010 Apr 27;6:139–54. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3160788/
16. Ohara DG, Melo C de S, Reis IMM dos, Jamami M. Functional capacity assessment of upper limbs in healthy young adult subjects. Fisioterapia em Movimento. 2017 Mar;30(1):159–67.
17. Edemekong PF, Bomgaars DL, Levy SB. Activities of Daily Living (ADLs) [Internet]. NCBI. StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470404/
18. KATZ S. Assessing Self-maintenance: Activities of Daily Living, Mobility, and Instrumental Activities of Daily Living. Journal of the American Geriatrics Society [Internet]. 1983 Dec;31(12):721–

7. Available from: https://pubmed.ncbi.nlm.nih.gov/6418786/
19. Lima VP, Velloso M, Almeida FD, Carmona B, Ribeiro-Samora GA, Janaudis-Ferreira T. Test–retest reliability of the unsupported upper-limb exercise test (UULEX) and 6-min peg board ring test (6PBRT) in healthy adult individuals. Physiotherapy Theory and Practice. 2018 Jan 19;34(10):806–12.
20. Lima VP, Brooks D, Konidis S, Araújo T, Ribeiro-Samora GA, Goldstein R, et al. Normative Values for the Unsupported Upper Limb Exercise Test and 6-Minute Pegboard and Ring Test in Healthy Canadian Adults. Physiotherapy Canada. 2020 Mar 30;72(4):e20190021.
21. Zhan S, Cerny FJ, Gibbons WJ, Mador MJ, Wu YW. Development of an Unsupported Arm Exercise Test in Patients With Chronic Obstructive Pulmonary Disease. Journal of Cardiopulmonary Rehabilitation. 2006 May;26(3):180–7.
22. Takahashi T, Jenkins SC, Strauss GR, Watson CP, Lake FR. A New Unsupported Upper Limb Exercise Test for Patients With Chronic Obstructive Pulmonary Disease. Journal of Cardiopulmonary Rehabilitation. 2003 Nov;23(6):430–7.
23. Franklin BA. Exercise Testing, Training and Arm Ergometry. Sports Medicine. 1985;2(2):100–19.
24. Janaudis-Ferreira T, Beauchamp MK, Goldstein RS, Brooks D. How Should We Measure Arm Exercise Capacity in Patients With COPD? Chest. 2012 Jan;141(1):111–20.
25. Kulkarni MS, Alaparthi GK, Krishnan S, Ramakrishna A, Acharya V. Reference value for the six-minute peg board and ring test. A cross sectional study. Multidisciplinary Respiratory Medicine. 2020 Jun 3;15(1).
26. McKeough ZJ, Velloso M, Lima VP, Alison JA. Upper limb exercise training for COPD. Cochrane Database of Systematic Reviews. 2016 Nov 15;11(11).
27. Elmorsy AS, Mansour AE, Okasha AE. Effect of upper limb, lower limb and combined training on exercise performance, quality of life and survival in COPD. Egyptian Journal of Chest Diseases and Tuberculosis. 2012 Jul;61(3):89–93.
28. Matsunaga H, Hitoshi Ayabe, Tomotoshi Imanaga, Moriwaki A, Eto J, Kikuchi C, et al. Effects Of Upper Limb And Thoracic Muscle Exercise In Chronic Obstructive Pulmonary Disease. American Journal of Respiratory and Critical Care Medicine. 2011 May 1;183:A1476–6.
29. Stark T, Walker B, Phillips JK, Fejer R, Beck R. Hand-held Dynamometry Correlation With the Gold Standard Isokinetic Dynamometry: A Systematic Review. PM&R [Internet]. 2011 May;3(5):472–9. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1934148210013250