Liliane Patrícia de Souza Mendes

NOVAS ESTRATÉGIAS PARA AVALIAÇÃO DE PESSOAS COM DEFICIÊNCIAS PULMONARES CRÔNICAS

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NEW APPROACHES TO ASSESS PEOPLE WITH CHRONIC PULMONARY DISABILITIES

Liliane Mendes, MScRhb (UFMG)

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Liliane Patrícia de Souza Mendes

NOVAS ESTRATÉGIAS PARA AVALIAÇÃO DE PACIENTES COM DEFICIÊNCIAS PULMONARES CRÔNICAS

Tese apresentada ao Programa de Pós-graduação em Ciências da Reabilitação da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da Universidade Federal de Minas Gerais, como requisito parcial à obtenção do título de Doutor em Ciências da Reabilitação.

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Orientadora: Profa. Dra. Verônica Franco Parreira

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PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS DA REABILITAÇÃO

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FOLHA DE APROVAÇÃO

NOVAS ESTRATÉGIAS PARA AVALIAÇÃO DE PESSOAS COM DEFICIÊNCIAS PULMONARES CRÔNICAS

LILIANE PATRÍCIA DE SOUZA MENDES

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ATA DA DEFESA DE TESE DA ALUNA
LILIANE PATRÍCIA DE SOUZA MENDES

Realizou-se, no dia 22 de março de 2019, às 13:30 horas, Auditório Professora Maria Lúcia Paixão, da Universidade Federal de Minas Gerais, a 79ª defesa de tese, intitulada *NOVAS ESTRATÉGIAS PARA AVALIAÇÃO DE PESSOAS COM DEFICIÊNCIAS PULMONARES CRÔNICAS*, apresentada por LILIANE PATRÍCIA DE SOUZA MENDES, número de registro 2015705567, graduada no curso de FISIOTERAPIA, como requisito parcial para a obtenção do grau de Doutor em CIÊNCIAS DA REABILITAÇÃO, à seguinte Comissão Examinadora: Prof(a). Veronica Franco Parreira - Orientador (Universidade Federal de Minas Gerais), Prof(a). Adriana Cláudia Lunardi (UNICID), Prof(a). Fabio de Oliviera Pitta (Universidade de Londrina), Prof(a). Danielle Aparecida Gomes Pereira (Universidade Federal de Minas Gerais), Prof(a). José Roberto Jardim (UNIFESP).

A Comissão considerou a tese:

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Finalizados os trabalhos, lavrei a presente ata que, lida e aprovada, vai assinada por mim e pelos membros da Comissão.
Belo Horizonte, 22 de março de 2019.

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Prof(a). Fabio de Oliviera Pitta (Doutor)

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RESUMO

A Organização Mundial de Saúde recomenda a utilização da Classificação Internacional de Funcionalidade, Incapacidade e Saúde (CIF) para avaliar de forma abrangente indivíduos com diferentes condições de saúde. A classificação considera os domínios de saúde e os domínios relacionados à saúde sendo descrita com base na estrutura e função do corpo, na atividade, e na participação. A inclusão dos domínios atividade e participação considera toda a experiência de saúde, ao invés do foco limitado aos aspectos da doença. Assim, uma avaliação de resultados centrada no paciente, deve medir todos os domínios, incluindo deficiências em estrutura e função do corpo, limitações em atividade e restrições em participação, a fim de considerar toda a experiência de saúde do indivíduo. Para melhor avaliação desses indivíduos, boas ferramentas de avaliação devem estar disponíveis, para observar deficiências, detectar limitações em atividade e identificar restrições em participação. Levando isso em consideração, essa tese avalia novas ferramentas para a avaliação de pessoas com deficiências pulmonares crônicas considerando todos os domínios da CIF. Nesse contexto, o Capítulo 1 apresenta uma síntese sobre a importância de uma avaliação abrangente da funcionalidade nas diferentes condições de saúde, principalmente na doença pulmonar obstrutiva crônica (DPOC), que é foco dessa tese. Na sequência, o Capítulo 2 apresenta uma revisão de literatura sobre três importantes aspectos que devem ser avaliados em pessoas com disfunções pulmonares crônicas dentro dos domínios da estrutura e função do corpo, da atividade, e da participação: o padrão respiratório, a capacidade funcional e o desempenho funcional, respectivamente. Esse capítulo apresenta ainda métodos de medidas do padrão respiratório, da capacidade funcional e do desempenho funcional. No Capítulo 3, o padrão

respiratório de 168 participantes saudáveis com idade entre 21 e 91 anos foi avaliado utilizando a pletismografia optoeletrônica com o objetivo de desenvolver valores de referência, que ainda não foram estabelecidos para esse instrumento. O estudo desenvolveu valores de referência para homens e mulheres para cada década de idade para indivíduos com idade entre 21 e 59 anos e também para aqueles com 60 anos ou mais. Esses valores serão importantes para comparação e melhor entendimento das alterações dessas variáveis em indivíduos com diferentes deficiências respiratórias que podem comprometer a função respiratória. O Capítulo 4 apresenta modificações de um teste utilizado para avaliar a capacidade funcional, o teste AVD-Glittre. Esse teste exige que os participantes realizem uma série de atividades diárias enquanto carregam uma mochila com peso, que pode afetar o seu equilíbrio. Dessa forma, foi realizado um estudo transversal randomizado para avaliação do teste AVD-Glittre com e sem mochila. Não foram observadas diferenças para as respostas fisiológicas e sintomas entre os testes com e sem mochila, exceto para a fadiga de membros superiores que foi reportada pelos homens como significativamente maior para o teste realizado com a mochila. Além disso, o teste de AVD-Glittre realizado sem a mochila foi responsivo a mudança após um programa de reabilitação pulmonar. Outras modificações do teste AVD-Glittre são apresentadas no Capítulo 5. O desfecho do teste é o tempo gasto para completar cinco voltas, no entanto, estudos prévios observaram que o consumo de oxigênio atinge um platô após a terceira volta. Esses achados sugerem que o teste AVD-Glittre pode ser realizado adequadamente em três voltas ao invés de cinco voltas. Por isso, o estudo no Capítulo 5 objetivou comparar as diferenças na execução do teste AVD-Glittre com e sem mochila em três e cinco voltas em pessoas com DPOC. Os principais achados deste estudo foram: os testes AVD-Glittre em três voltas com e sem mochila provocaram os mesmo

sintomas e dessaturação de oxigênio que o teste realizado em cinco voltas, exceto para frequência cardíaca que foi significativamente maior para o teste em cinco voltas. Ambos os testes foram responsivos à mudança após um programa de reabilitação pulmonar. No Capítulo 6, um novo teste para avaliação da capacidade de *endurance* para atividades funcionais foi desenvolvido e avaliado - o teste *Glittre Endurance*. O desenvolvimento de um teste de *endurance* se justifica porque testes de *endurance*, como o *Endurance Shuttle Walk Test* tem demonstrado ser mais sensível a mudança após intervenções como a reabilitação pulmonar comparado ao *Incremental Shuttle Walk Test* ou Teste de Caminhada de Seis Minutos. Isso acontece porque pessoas com DPOC após um programa de reabilitação pulmonar normalmente não conseguem melhorar significativamente a velocidade com que eles realizam as atividades, mas podem conseguir realizar as atividades por mais tempo, com menos dispneia e fadiga. Afim de avaliar a capacidade de *endurance* para atividades diárias, 52 participantes com DPOC foram recrutados para desenvolver e avaliar o teste *Glittre Endurance*. Os principais achados foram: o teste *Glittre Endurance* foi desenvolvido e apresentou um efeito aprendizado quando um segundo teste foi realizado, o tempo do teste *Glittre Endurance* não se correlacionou com os desfechos de qualquer outro teste de campo e o teste *Glittre Endurance* foi responsivo após um programa de reabilitação pulmonar. O estudo no Capítulo 7 avalia a relação entre a capacidade funcional (medida pelos testes AVD-Glittre com e sem mochila e o teste *Glittre Endurance*) comparado com atividades físicas diárias medidas por um acelerômetro usado por sete dias. Esse estudo objetivou determinar qual dos testes Glittre melhor representa as atividades físicas diárias em pessoas com DPOC. Os principais achados foram: o tempo de teste do AVD-Glittre correlacionou moderadamente com número de passos

e tempo gasto em atividades moderadas, o teste AVD-Glittre realizado sem a mochila correlacionou moderadamente com o número de passos, e o tempo de teste do *Glittre Endurance* correlacionou moderadamente com o número de passos e tempo gasto em atividades vigorosas. O capítulo 8 integra os principais achados dos estudos da tese e apresenta implicações clínicas dos achados e sugestões de áreas para pesquisas futuras.

Palavras-chave: padrão respiratório, capacidade funcional, teste AVD-Glittre

ABSTRACT

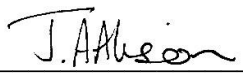
The World Health Organization recommends the use of the International Classification of Functioning, Disability, and Health (ICF) to comprehensively assess individuals with different health conditions. The classification considers health domains and health-related domains and is described on the basis of body functions and structure, activity, and participation. The inclusion of activities and participation considers the whole health experience, rather than a limited focus on aspects of the diseases. A patient-centred outcome assessment thus, should measure all domains including impairments in body functions and structure, limitations to activities and restrictions of participation in order to consider the whole health experience of the individual. Thus good evaluation tools should be available to assess impairments, detect activity limitations and identify participation restrictions. This thesis evaluates new approaches to assess people with chronic pulmonary disabilities in all ICF domains. In this context, Chapter 1 provides a summary of comprehensive assessments of functioning in health conditions, particularly chronic obstructive pulmonary disease (COPD), which is the focus of this thesis. Chapter 2 presents a literature review of three important areas to be assessed in people with chronic pulmonary disabilities, based on the ICF domains of body function and structure, activity, and participation, which are the pattern of breathing, functional capacity, and functional performance, respectively. This chapter also presents methods of measurement of breathing pattern, functional capacity and functional performance. In Chapter 3, the pattern of breathing of 168 healthy participants in age ranges from 21 to 91 years was assessed using optoelectronic plethysmography with the aim of developing reference values, which have not been previously established. The study developed reference values for males and females for each ten-year increment in age

for individuals aged from 20 to 59 years, and also a reference value for those aged 60 years and above. These reference values will be important for comparison and better understanding of the alterations of these variables in individuals with different respiratory impairments that may compromise respiratory function. Chapter 4 presents modifications to a test of functional capacity, the Glittre-ADL test. This test requires participants to perform a series of daily activities while wearing a weighted backpack, which may affect balance. The study in this chapter evaluated the Glittre-ADL test with and without a backpack in a randomised crossover study design. There were no differences between the tests with and without the backpack in physiological response and symptoms, except for upper limb fatigue that was reported by males as significantly higher for the test performed with the backpack. In addition, the Glittre-ADL test performed without the backpack was responsive to change following a pulmonary rehabilitation program. Further modifications of the Glittre-ADL test are presented in Chapter 5. The outcome of the test is the time taken to complete five laps of the test, however previous studies have observed that oxygen consumption reached a plateau after the third lap. These findings suggest that the Glittre-ADL test might be adequately performed in three laps instead of five laps. The study in Chapter 5 aimed to compare the differences in performance of the Glittre-ADL test with and without the backpack in three and five laps in people with COPD. The main findings of this study were that the three lap Glittre-ADL test both with and without the backpack provoked the same symptoms and oxygen desaturation as the 5-lap test, except for heart rate that was significantly higher for the 5-lap test, and that the tests were responsive to change following a pulmonary rehabilitation program. In chapter 6, a new test of endurance capacity for functional activities, the Glittre Endurance test, was developed and evaluated. The rationale for

developing an endurance test was that endurance tests, such as the endurance shuttle walk test, have been shown to be more sensitive to change after interventions like pulmonary rehabilitation compared to the incremental shuttle walk test or the six-minute walk test. This is because people with COPD after a pulmonary rehabilitation program often cannot significantly improve the speed with which they perform activities, but may be able to perform activities for longer, with less breathlessness and fatigue. In order to evaluate endurance capacity for daily activities, 52 participants with COPD were recruited to develop and evaluate the Glittre Endurance test. The main findings were that a Glittre Endurance test was developed which showed a learning effect when a second Glittre Endurance test was performed; the Glittre Endurance test time did not correlate with the outcomes of any other field tests; and that the Glittre Endurance test was responsive to change following a pulmonary rehabilitation program. The study in Chapter 7 evaluated the relationship between functional capacity (measured by the Glittre-ADL tests with and without the backpack and the Glittre Endurance test) compared with daily physical activity measured by an accelerometer worn for seven days. The study aimed to determine which Glittre tests best represented daily physical activity in people with COPD. The main findings were that Glittre-ADL test time correlated moderately with number of steps and time spent in moderate activities; Glittre-ADL test time performed without the backpack time was moderately correlated with number of steps; Glittre Endurance test time was moderately correlated with number of steps per day and moderately correlated with time spent in vigorous activities. Chapter 8 integrates the main findings of the studies within the thesis and provides clinical implications of the findings and suggestions of areas for future research.

Keywords: breathing pattern, functional capacity, Glittre-ADL test

This is to certify that the thesis entitled "**NEW APPROACHES TO ASESS PEOPLE WITH CHRONIC PULMONARY DISABILITIES**" submitted by **LILIANE MENDES** in fulfilment of the requirements for the degree of Doctor of Philosophy is in a form ready for examination.

Signed 

Date 01/03/2019

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Signed 

Date 01/03/2019

Professor Verônica Franco Parreira
Department of Physiotherapy,
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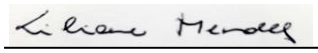
I, **LILIANE MENDES**, hereby declare that the work contained within this thesis is my own and has not been submitted to any other university or institution as a part or a whole requirement for any higher degree.

In addition, ethical approval from the University of Sydney Human Ethics Committee was granted for three of studies that were carried out in Australia and presented in this thesis. Participants were required to read a participant information document and informed consent was gained prior to data collection.

Name Liliane Patrícia de Souza Mendes

Signed 

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PREFACE

This thesis was prepared in compliance with the rules established by the Rehabilitation Sciences Program of the Universidade Federal de Minas Gerais (UFMG) and the University of Sydney (USYD), according to conditions established by the student cotutelle agreement reached on October 2016. This thesis was conducted as a partial requirement to obtain the degree of Doctor in Rehabilitation Sciences by the UFMG, Brazil, and the degree of Doctor of Philosophy by the USYD, Australia.

The Program in Rehabilitation Sciences of the UFMG requires: (1) the accomplishment of 36 credits; (2) the writing, oral defence, and approval of a research project; and (3) the presentation of a prof of the submission of one paper related to the thesis and the proof of at least one paper published during the doctorate period.

The USYD requires: (1) the candidature divided between the institutions, with a minimum of 30% of the candidature to be undertaken at each institution; (2) adequate English proficiency confirmed by IELTS or TOEFL IBT.

Thus, both institutions agreed three distinct doctorate phases: The first phase occurred from April 2015 to March 2017 and it was held in UFMG. This phase included the completion of the required coursework; the renewal of the principal cotutelle agreement between institutions for the period of five years; the establishment of the student cotutelle agreement; the participation in two distinct selection process to obtain scholarships for the period overseas; project data collection; the approval on both scholarship selection process (Programa de Doutorado-sanduíche no Exterior (PDSE) Process number 88881.135337/2016-01

and Endeavour Leadership Program of the Australian Government – Department of Education and Training); approval on English proficiency test; the writing, oral defence and approval of the research project; and the supervision of four undergraduate final course assignments, which resulted in two publications:

1. MENDES, L.P.S.; TEIXEIRA, L.S.; DA CRUZ, L.J.; VIEIRA, D.S.R.; PARREIRA, V.F. Sustained maximal inspiration has similar effects compared to incentive spirometers. Respiratory Physiology & Neurobiology, v. 261, p. 67-74, 2019.

2. MENDES, L.P.S.; MALTA, F.F.; ENNES, T.O.; RIBEIRO-SAMORA, G.A.; DIAS, R.C.; ROCHA, B.L.C.; RODRIGUES, M., BORGES, L.F., PARREIRA, V.F. Prediction equation for the mini-mental state examination: influence of education, age, and sex. Fisioterapia e Pesquisa, in press, 2019.

Another publications of the doctorate period were:

1. MENDES, L.P.S.; VIEIRA, D.S.R.; GABRIEL, L.S.; RIBEIRO-SAMORA, G.A.; ANDRADE, A.D.; BRANDAO, D.C.; FREGONEZI, G.; GOES, M.C.R.; BRITTO, R.R.; PARREIRA, V.F. Influence of posture, age, and sex on breathing pattern and chest wall motion in healthy subjects. Brazilian Journal of Physical Therapy, in press, 2019.

2. MENDES, L.P.S.; MORAES, K.S.; HOFFMAN, M.; VIEIRA, D.S.R.; SAMORA, G.A.R.; LAGE, S.M.; BRITTO, R.R.; PARREIRA, V.F. Effects of diaphragmatic breathing with and without pursed-lips breathing in subjects with COPD. Respiratory Care, v. 64 (2), p. 136-144, 2019.

3. TORRES, J.L.; DA SILVA, S.L.A.; FERREIRA, F.R.; MENDES, L.P.S.; MACHADO, L.A. Chronic pain is associated with increased health care use among community-dwelling older adults in Brazil: the pain in the elderly (PAINEL Study).

Family Practice Clinical Journal of Pain, in press, 2018.

4. PEREIRA, D.; NEVES, V.; MONTEMEZZO, D.; PARREIRA, V.; ALENCAR, M.C.; MENDES, L. P.; PEREIRA, L., BRITTO R., PARREIRA, V.F. Prognostic value of VE/VCO2 and interleukin-6 in chronic heart failure subjects. IJC Metabolic & Endocrine, v.14, p. 65-66, 2017.

5. MACHADO, L.A.C.; VIANA, J.U.; DA SILVA, S.L.A.; COUTO, F.G.P.; MENDES, L.P.; FERREIRA, P. H.; PEREIRA, L., MANUELA L.F., DIAS, J.M.D.; DIAS, R.C. Correlates of a recent history of disabling low back pain in community-dwelling older persons. Clinical Journal of Pain, v.35, p. 43-51, 2017.

6. COSTA, A.B.P.; MACHADO, L.A.C.; DIAS, J.M.D; DE OLIVEIRA, A.K.C.; VIANA, J.U.; DA SILVA, S.L.A.; COUTO, F.G.P.; TORRES, J.L.; MENDES, L.P.; DIAS, R.C. Nutritional risk is associated with chronic musculoskeletal pain in community-dwelling older persons: the PAINEL study. Journal of Nutrition in Gerontology and Geriatrics, v.1, p. 1, 2016.

The second phase was held in USYD from April 2017 to June 2019 and included approval of the project at Ethics Committee; participation in 10 workshops (Systematic Review, Effects size, Research data management plan, Progress plans, Presentation skills workshop, Pronunciation skills, Oral presentation, Systematic review workshop, Bayesian breakfast: to p or not to p?, and The future we were promised: How partnerships in digital health are transforming care); one symposium (Sydney Innovation and Research Symposium); one seminar (Better living with your lung disease); two conferences (12th National Allied Health Conference and Physiotherapy Conference 2017, the last one where I had the opportunity to present my works on Glittre tests in the workshop: Physical activity and sedentary behaviour

in chronic and acute cardiorespiratory care); one forum (SLHD Allied Health Research Forum 2017); data collection; enrolment in two different projects as a research assistantship ("Randomized controlled trial of balance training for fall reduction in individuals with COPD", in partnership with Canada, and "Effect of a pulmonary rehabilitation programme of eight weeks duration compared to twelve weeks on exercise capacity in people with chronic obstructive pulmonary disease (PuRe Duration) – a randomised controlled trial"); and submission of abstracts for two international conferences. The University of Sydney financed the participation in the conferences.

The last phase occurred from July 2018 to February 2019 and included data collection and processing, and writing of the thesis and related papers. I also gained experience in supervision by being the co-supervisor of a research master's student. In addition, I presented two posters related to the thesis in the European Respiratory Society International Conference 2018 in Paris. The abstracts were published in a Q1 journal with a high impact factor of 12.2.

1. MENDES, L.P.S; SPENCER, L.; ZAFIROPOULOS, B.; PARREIRA, V.F.; ALISON, J. Glittre-ADL performance with and without a backpack. European Respiratory Journal, v. 52, PA1436.

2. MENDES, L.P.S; SPENCER, L.; ZAFIROPOULOS, B.; PARREIRA, V.F.; ALISON, J. Glittre-ADL test performed in 3 laps as an alternative to the 5 laps test. European Respiratory Journal, v. 52, PA1437.

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ABBREVIATIONS

AB	Abdomen
ADL	Activity of daily living
ATS	American Thoracic Society
AVD	Atividades de vida diária
BMI	Body mass index
BP	Backpack
bpm	Beats per minute
CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
CAT	COPD Assessment Test
CIF	Classificação Internacional de Funcionalidade, Incapacidade e Saúde
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico
COPD	Chronic Obstructive Pulmonary Disease
CPET	Cardiopulmonary exercise testing
DPOC	Doença Pulmonar Obstrutiva Crônica
Dra.	Doutora
EEFFTO	Escola de Educação Física, Fisioterapia e Terapia Ocupacional
ESWT	Endurance shuttle walk test
FAPEMIG	Fundação de Amparo à Pesquisa do Estado de Minas Gerais
FEV_1	Forced expiratory volume in one second
FEV_1/FVC	Ratio of forced expiratory volume in one second and forced vital capacity

FVC	Forced vital capacity
GOLD	Global Initiative for Chronic Obstructive Lung Disease
HAP	Human activity profile
HR	Heart rate
HRQoL	Health-related quality of life
ICF	International Classification of Functioning, Disability, and Health
IELTS	International English Language Testing System
ISWT	Incremental shuttle walk test
Kg/m^2	Kilograms per metre squared
Kph	kilometres per hour
LCADL	London Chest of Daily Living
m	Metres
m/s	Metres per second
MID	Minimal important difference
MMSE	Mini-Mental State Examination
OEP	Optoelectronic plethysmography
PDSE	Programa de Doutorado-sanduíche no exterior
PFSDQ	Pulmonary Functional Status and Dyspnoea Questionnaire
PROCAD	Pró-reitoria de coordenação acadêmica
PROEX	Pró-reitoria de extensão
RC	Rib cage

RCa	Abdominal rib cage
RCp	Pulmonary rib cage
RCT's	Randomized controlled trials
RescaRM	Respiratory and Cardiac Rehabilitation and Management
Rho	Spearman correlation coefficient
RPE	Rate of perceived exertion
RR	Respiratory rate
s	Seconds
SD	Standard deviation
SGRQ	St George's Respiratory Questionnaire
SLHD	Sydney Local Health District
SpO_2	Peripheral oxygen saturation
SPSS	Statistical Package for the Social Sciences
TCC	Trabalho de conclusão de curso
Ti	Inspiratory time
Ti/Ttot	Duty cycle
Te	Expiratory time
TOEFL IBT	Test of English as a Foreign Language Internet Based Test
Ttot	Total time of respiratory cycle
UFMG	Universidade Federal de Minas Gerais
V_{AB}	Abdomen tidal volume
$V_{AB\%}$	Abdomen percentage contribution

V_{cw}	Chest wall tidal volume
V_{cw}/Ti	Mean inspiratory flow
V_{cw}/Te	Mean expiratory flow
VE	Minute ventilation
Vee_{AB}	End-expiratory abdomen volume
Vee_{cw}	End-expiratory chest wall volume
Vee_{RCa}	End-expiratory abdominal rib cage volume
Vee_{RCp}	End-expiratory pulmonary rib cage volume
Vei_{AB}	End-inspiratory abdomen volume
Vei_{cw}	End-inspiratory chest wall volume
Vei_{RCa}	End-inspiratory abdominal rib cage volume
Vei_{RCp}	End-inspiratory pulmonary rib cage volume
V_{RCa}	Abdominal rib cage tidal volume
V_{RCp}	Pulmonary rib cage tidal volume
$V_{RCa\%}$	Abdominal rib cage percentage contribution
$V_{RCp\%}$	Pulmonary rib cage percentage contribution
VO_2	Oxygen consumption
USYD	University of Sydney
WHO	World Health Organization
W/out	Without
6MWT	Six-minute walk test
95%CI	95 percent confidence interval

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1. MENDES, L.P.S; SPENCER, L.; ZAFIROPOULOS, B.; PARREIRA, V.F.; ALISON, J. Teste Glittre-ADL: a mochila faz diferença para o desempenho no teste? Assobrafir Ciência, v. 9 (Supl1): 95-484, PT230, 2018.

2. MENDES, L.P.S; SPENCER, L.; ZAFIROPOULOS, B.; PARREIRA, V.F.; ALISON, J. Teste Glittre-ADL executado em três voltas como alternativa para o teste de cinco voltas. Assobrafir Ciência, v. 9 (Supl1): 95-484,PT229, 2018.

3. MENDES, L.P.S; SPENCER, L.; ZAFIROPOULOS, B.; PARREIRA, V.F.; ALISON, J. Teste Glittre Endurance: um novo teste para avaliação da capacidade functional de pacientes com doença pulmonar obstrutiva crônica. Assobrafir Ciência, v. 9 (Supl1): 95-484, PT231, 2018.

4. MENDES, L.P.S; SPENCER, L.; ZAFIROPOULOS, B.; PARREIRA, V.F.; ALISON, J. Glittre-ADL performance with and without a backpack. European Respiratory Journal, v. 52, PA1436, 2018.

5. MENDES, L.P.S; SPENCER, L.; ZAFIROPOULOS, B.; PARREIRA, V.F.; ALISON, J. Glittre-ADL test performed in 3 laps as an alternative to the 5 laps test. European Respiratory Journal, v. 52, PA1437, 2018.

6. MENDES, L.P.S; BARBOSA, M. H.; GABRIEL, L. S.; RIBEIRO-SAMORA, G.; FREGONEZI, G. F.; ANDRADE, A. D.; BRITTO, R. R.; PARREIRA, V.F. Influence of posture, gender, and sex on breathing pattern and chest wall motion during quiet breathing in healthy subjects. European Respiratory Journal, v. 46, PA4218, 2015.

CONFERENCE PRESENTATIONS - ORAL

Pre conference workshop: Physical activity behaviour in chronic and acute cardiorespiratory care – Glittre-ADL test. Physiotherapy Conference, 2017.

CONFERENCE PRESENTATIONS - POSTER

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2. MENDES, L.P.S; SPENCER, L.; ZAFIROPOULOS, B.; PARREIRA, V.F.; ALISON, J. Glittre-ADL test performed in 3 laps as an alternative to the 5 laps test. European Respiratory Society International Conference, v. 52, PA1437, 2018.

3. MENDES, L.P.S; BARBOSA, M. H.; GABRIEL, L. S.; RIBEIRO-SAMORA, G.; FREGONEZI, G. F.; ANDRADE, A. D.; BRITTO, R. R.; PARREIRA, V.F. Influence of posture, gender, and sex on breathing pattern and chest wall motion during quiet breathing in healthy subjects. European Respiratory Society International Conference, v. 46, PA4218, 2015.

CHAPTER 1

INTRODUCTION

This chapter will summarize the importance of a comprehensive assessment of functioning in health conditions, particularly chronic obstructive pulmonary disease (COPD), which is the focus of this thesis.

ASSESSMENT OF FUNCTIONING: THE INTERNATIONAL CLASSIFICATION OF FUNCTIONING, DISABILITY AND HEALTH (ICF)

The World Health Organization (WHO) recommends the use of the International Classification of Functioning, Disability, and Health (ICF) to comprehensively assess individuals with different health conditions (World Health Organization 2001& 2002). This classification promotes a unified view of various dimensions of health, suggests a biopsychosocial model, and tries to establish a common language spoken by health professionals (World Health Organization 2001& 2002).

The domains of the classification can be considered as health domains and health-related domains and are described on the basis of body functions and structure, activity, and participation (Figure 1) (World Health Organization, 2001). The inclusion of individuals' functioning in activities and participation considers the whole health experience, rather than a limited focus on aspects of the diseases (Bui, Nyberg, Maltais & Saey 2017). Therefore, the framework helps health professionals in describing a person's impairments in body functions and structure as well as assessing the level of capacity observed in a standard environment (i.e. activity) and

the level of performance observed in a usual environment (i.e. participation) (World Health Organization 2001 & 2002).

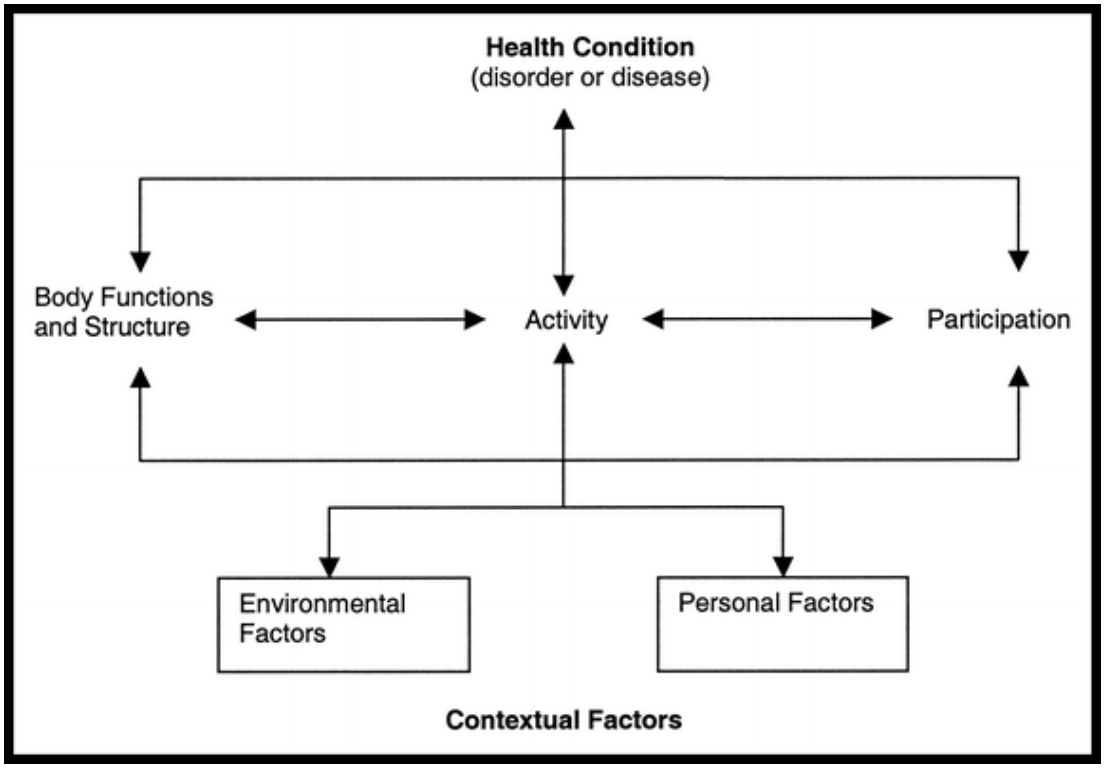


Figure 1. International Classification of Functioning, Disability, and Health (ICF) (World Health Organization 2002).

The 'body functions and structure' domain refers to physiological functions of body systems as well as to anatomical parts of the body. Impairment is the term used to refer to problems in body function or structure. The 'activity' domain refers to carrying out a task or an action by an individual. The term 'activity limitations' are difficulties that an individual might have in carrying out these tasks or actions. The 'participation' domain refers to involvement or participation in life situations (e.g. work, society, family) and the term 'participation restrictions' is used for difficulties that an individual may experience in participating in life situations (World Health Organization 2001 & 2002).

Health professionals can use the term ‘functioning’ to refer to all body functions, activities, and participation, and ‘disabilities’ to refer to the dysfunction at one or more levels of the ICF classification i.e. impairments in body functions or structure, activity limitations, and participation restrictions. The ICF also considers contextual factors that involve environmental and personal factors. Environmental factors include the physical, social and attitudinal environment in which individuals live and conduct their lives. The ICF, thus, represents the interaction of all these factors (World Health Organization 2001 & 2002).

Within each domain, qualifiers are used to indicate the levels of dysfunction. For the body function and structure domain, the qualifier can indicate the degree of the impairment on body functions or structure as: no impairment, mild, moderate, severe, and complete. For the activity domain, the qualifier describes the capacity of an individual to carry out a task. For the participation domain, the qualifier indicates what the individual can perform in the real environment (World Health Organization 2001 & 2002).

Assessment of functioning in chronic pulmonary disabilities

Chronic pulmonary disabilities involve any impairment in body function or structure, any limitation in activity, and any restriction in participation as a result of a lung condition. Adequate information about functioning and disabilities obtained by the initial assessment is crucial to guide clinicians to design appropriate rehabilitation interventions. In this context, the ICF is a useful tool to assess all these aspects.

With the aim to make ICF more applicable for everyday use in clinical practice, WHO and the ICF Research Branch developed core sets over the 1400 ICF categories. ICF core sets provide a list of essential categories that are relevant for

specific health conditions and health care contexts, facilitating the description of functioning. This selection was based on preparatory studies and involvement of a group of experts (Cieza et al., 2004). In 2004, 17 experts from eight countries with various professional backgrounds developed an ICF Core Set for Obstructive Pulmonary Diseases (Cieza et al., 2004; Bui et al., 2017). Among all Obstructive Pulmonary Diseases this thesis will focus on COPD.

OVERVIEW OF COPD

COPD is a disease of the airways (chronic bronchitis) and lung parenchyma (emphysema) caused by exposure to noxious particles or gases (Global Initiative for Chronic Obstructive Lung Disease, 2019). Chronic asthma may be encompassed within COPD because it involves narrowing of the airways due to bronchial hyper-responsiveness, airway inflammation and hypertrophy of mucus glands. However, chronic asthma differs in aetiology from COPD because the airflow limitation can be reversible (Global Initiative for Chronic Obstructive Lung Disease, 2019; Guidelines for the Diagnosis and Management of Asthma, 2007).

The greatest risk factor for developing COPD is tobacco smoking. In some countries, other risk factors are indoor or outdoor air pollution from burning wood or other fuels (Global Initiative for Chronic Obstructive Lung Disease, 2019; Eisner et al., 2010; Salvi & Barners, 2009). The risk of developing COPD can be also related to aging, asthma and genetic factors such as alpha-1-antitrypsin deficiency (Global Initiative for Chronic Obstructive Lung Disease, 2019; Ito & Barnes, 2009; Stoller & Aboussouan, 2005).

Currently, COPD is the fourth leading cause of death in the world and projected to become the third leading cause of death in three years due to continued

exposure to risk factors and population aging (Global Initiative for Chronic Obstructive Lung Disease, 2019; Lozano et al., 2012; World Health Organisation, 2008). In addition, COPD is a leading cause of morbidity, which is an important public health concern (Global Initiative for Chronic Obstructive Lung Disease, 2019). In Australia, COPD is the fifth leading cause of death and affects 1.5 million Australians, including 1 in 13 people over 40 years of age (Toelle et al., 2013). In Brazil, COPD is also prevalent being between the fifty to sixty leading cause of death and affecting approximately 6 million Brazilians, 18% of men and 14% of women over 40 years of age (Rabahi, 2013; Menezes et al., 2005). The economic impact of the disease is huge and the costs estimated in hospital admissions were $929 million for Australia and $41.2 million for the Public Health System from Brazil, being higher than the cost of acute myocardial infarction and systemic arterial hypertension (Australian Institute of Health and Welfare, 2014; Brazilian Ministry of Health, 2019).

The diagnosis of COPD involves a detailed medical history and spirometry. COPD should be considered in any individual who presents with dyspnoea, chronic cough or sputum production and/or a history of exposure to risk factors, particularly smoking. Spirometry should measure the forced vital capacity (FVC) which is the volume of air forcibly exhaled from the point of maximal inspiration and forced expiratory volume in one second (FEV_1) which is the maximum air volume exhaled during the first second of the manoeuvre and the ratio of FEV_1/FVC can be calculated. A $FEV_1/FVC < 0.70$ after bronchodilator administration is required to confirm the presence of airflow limitation (Global Initiative for Chronic Obstructive Lung Disease, 2019).

Chronic and progressive dyspnoea is the most common symptom of COPD and cough with sputum production is present in up to 3 of 10 individuals (Kessler et al., 2011). Additional symptoms are wheezing, fatigue, weight loss and anorexia, with weight loss and anorexia particularly in individuals with severe and very severe COPD. Symptoms may vary over the progression of the disease and from day-to-day (Global Initiative for Chronic Obstructive Lung Disease, 2019; Kessler et al., 2011).

The assessment of individuals with COPD includes establishing the impairments, the severity of the disease, the severity of symptoms, the activity limitations, the participation restrictions, the risk of exacerbations, and the presence of comorbidities (Global Initiative for Chronic Obstructive Lung Disease, 2019; World Health Organization 2001& 2002). The classification of the severity of the disease airflow limitation is based on FEV_1 according with Table 1.

Table 1 – Classification of airflow limitation severity in COPD in individuals with $FEV_1/FVC < 0.70$

GOLD I	Mild	$FEV_1 \geq 80\%$ predicted
GOLD II	Moderate	$50\% \leq FEV_1 < 80\%$ predicted
GOLD III	Severe	$30\% \leq FEV_1 < 50\%$ predicted
GOLD IV	Very severe	$FEV_1 < 30\%$ predicted

Source: Adapted from Global Initiative for Chronic Obstructive Lung Disease, 2019

The most widely used measure of symptoms in people with is the COPD Assessment Test (CAT™), which is a validated measure available in several languages (Silva, Morano, Viana, Magalhaes & Pereira, 2013; Jones et al., 2009). The cut-point used for considering regular treatment of symptoms is 10 (Global

Initiative for Chronic Obstructive Lung Disease, 2019; Silva, et al., 2013; Jones et al., 2009).

Exacerbations are characterized by an acute worsening of respiratory symptoms and may require additional therapy. Exacerbations are classified as mild when treated with short-acting bronchodilators; moderate when treated with antibiotics and/or oral corticosteroids added to short-acting bronchodilators; or severe when the individuals require hospitalization or visit the emergency department (Global Initiative for Chronic Obstructive Lung Disease, 2019; Hurst & Wedzicha, 2007; Burge & Wedzicha, 2003). Greater disease severity is associated with an increased risk of exacerbations and death (Hurst et al., 2007), and hospitalizations due to exacerbations are associated with poor prognosis and risk of death (Soler-Catalluna et al., 2005).

Common comorbidities of COPD are cardiovascular disease, skeletal muscle dysfunction, depression and anxiety. Skeletal muscle dysfunction is caused by different factors such as inactivity, poor diet, systemic inflammation and hypoxia and can contribute to exercise intolerance (Global Initiative for Chronic Obstructive Lung Disease, 2019; Maltais et al., 2014).

ICF CORE SETS FOR OBSTRUCTIVE PULMONARY DISEASES

For obstructive pulmonary diseases, that encompass COPD, two types of ICF core sets have been developed: the comprehensive and the brief. The comprehensive consists of 71 categories: 19 assess body functions, 5 assess body structures, 24 assess activity and participation and 23 assess environmental factors. Personal factors were not classified by ICF core sets for Obstructive Pulmonary Diseases. The brief version consists of 17 categories: 5 assess body functions, 3 the body structures, 5

assess activity and participation and 4 the environmental factors (Cieza et al., 2004). The comprehensive core set (Figure 2) allows the collection of more information and it can be used to guide multidisciplinary assessments in the rehabilitation process. The brief core set (Figure 3) is composed of minimum data and can be used for any clinical encounter (Mpofu & Oakland 2010; Cieza et al., 2004).

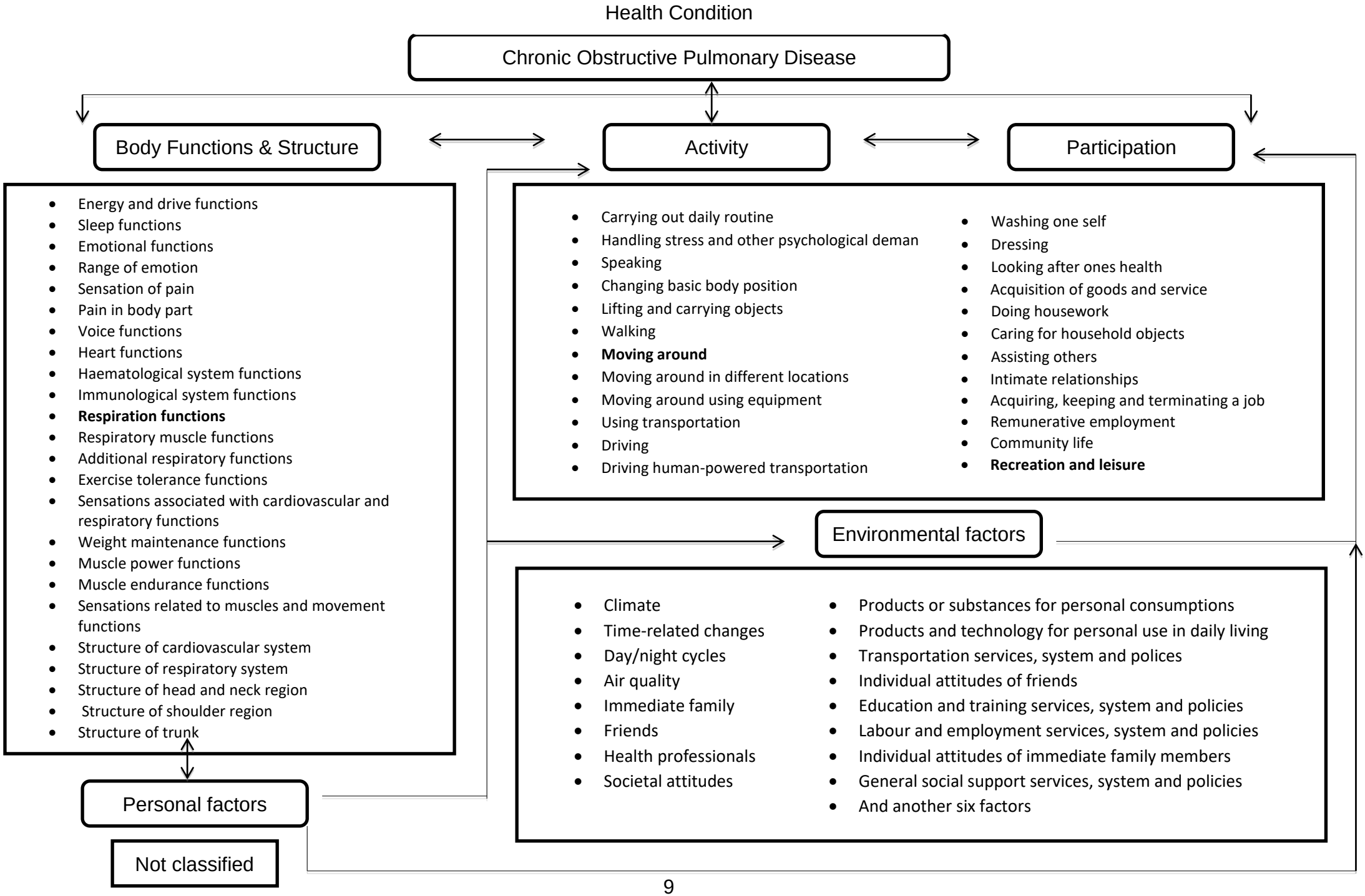


Figure 2. ICF Comprehensive Core Set for chronic obstructive pulmonary disease. Adapted from Stucki et al, 2004.

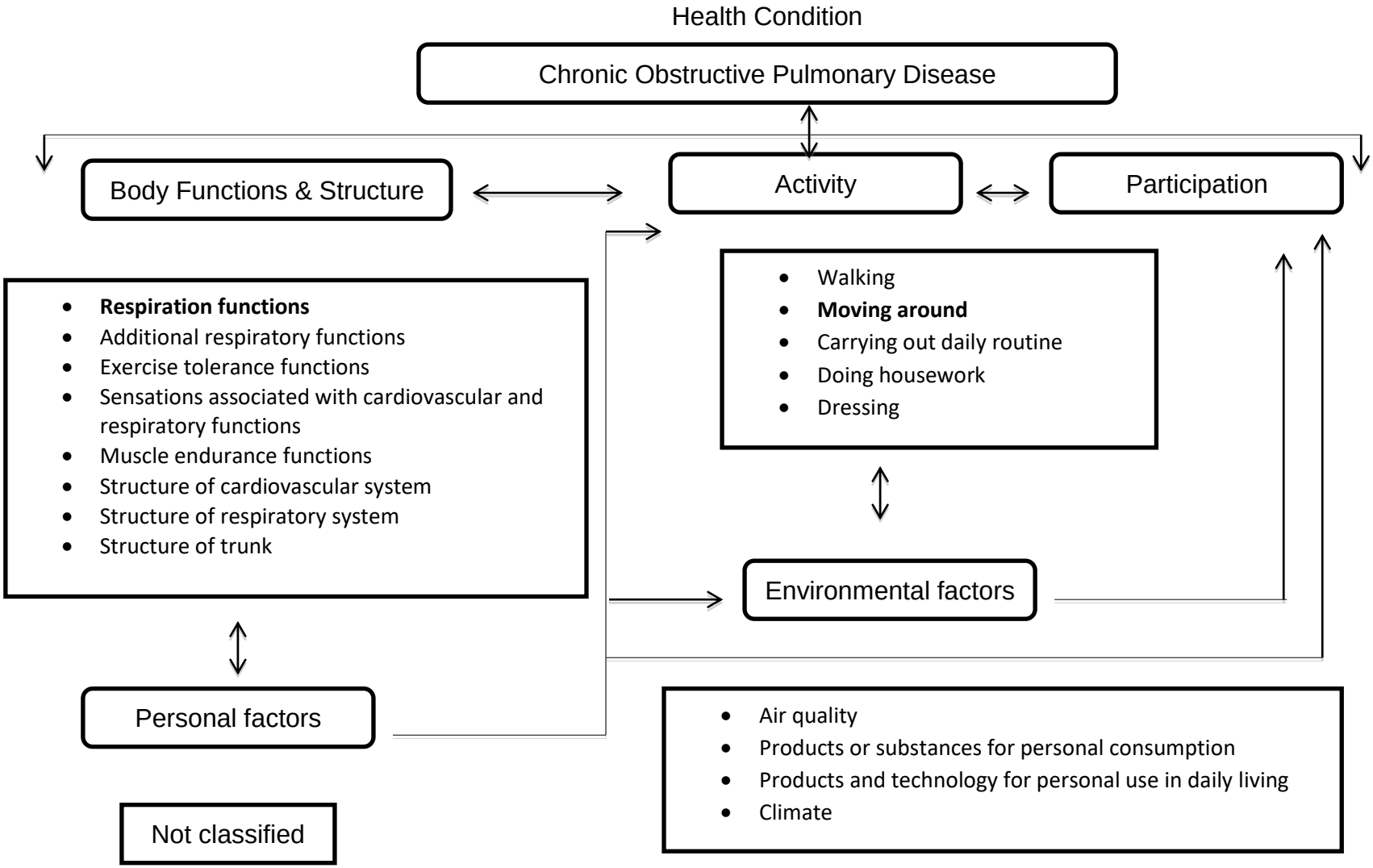


Figure 3. ICF Brief Core Set for chronic obstructive pulmonary disease. Adapted from Stucki et al., 2004.

According to ICF brief core set the most frequent impairments of body functions and structure related to obstructive pulmonary disease are: structure of respiratory system, respiration functions, and exercise tolerance functions (100% each); sensations associated with cardiovascular and respiratory functions (92%); and structure of cardiovascular system (83%). The most frequent limitation in activities and restrictions in participations are: walking and moving around (100% each) and carrying out daily routine and doing housework (58%). The most frequent barriers in the environment are: air quality and products or substances for personal consumption (100% each). The percentages correspond to the consensus of the experts for inclusion of the categories in the ICF brief core set based on evidence and their opinions (Stucki et al., 2004).

A patient-centred outcome assessment measuring all domains including activity and participation beyond the assessment of body functions and structure is crucial to consider the whole health experience of the individual (Bui et al., 2017). To better assess these individuals, good evaluation tools should be available to observe impairments, detect activity limitations and identify participation restrictions. Taking this into consideration, this thesis evaluates new approaches to the assessment of patients with chronic pulmonary disabilities in all ICF domains.

To contribute to the assessment in body functions and structure, this thesis proposes reference values for breathing pattern in three different postures using optoelectronic plethysmography. Establishing these reference values will be important for future comparisons of people with chronic pulmonary disabilities to better identify impairments at the ICF core set “respiration functions”, which is one of the most frequent impairments in this domain (Stucki et al., 2004; Jácome, Marques, Gabriel & Figueiredo, 2013).

To assess activity limitation, this thesis evaluates modifications to the Glittre ADL-Test, which has been used to assess functional capacity of individuals with COPD, and the development of a new tool, the Glittre Endurance Test. Recently, the Glittre ADL-Test was considered the most promising and comprehensive test to assess patients with COPD (Bui et al., 2017) as it includes 11 links to ICF which are: changing basic position (sitting, standing and bending); lifting and carrying objects (lifting and carrying on shoulders, hip and back); fine hand use (putting down objects and grasping); hands and arm use (releasing and reaching); walking and moving (walking short distances) and moving around (climbing) that are all important for mobility and daily participation in physical activities (Bui et al., 2017). The modifications of the Glittre-ADL test evaluated in this thesis are the Glittre-ADL test performed without the backpack and performed in three laps instead of five laps, which may contribute to a safer and more practical test, respectively. The proposed Glittre Endurance Test will still include all these ICF links and will also assess endurance capacity which is important for daily function and has been shown to be responsive to change following pulmonary rehabilitation in the COPD population (Eaton, Young, Nicol & Kolbe, 2006). The Glittre tests will help clinicians to better identify limitations at the ICF core set "moving around", which is one of the main limitations observed by health professionals (Stucki et al., 2004) and also confirmed from the patients' perspective (Jácome et al., 2013).

This thesis also investigates the new accelerometer, Axivity that measures the number of daily steps and physical activity levels. This accelerometer is a promising tool for studies with COPD individuals as it is waterproof, thus it allows the assessment of these individuals for the whole time, including bathing, that is an activity known to cause breathlessness in these individuals (Velloso & Jardim, 2006).

Functional performance can be investigated by direct observation in an individual's real environment and/or by questionnaires (Bui et al., 2017). In this context, the Axivity and the St George's Respiratory Questionnaire are appropriate tools and were used in this thesis to evaluate the domain participation and the core sets "recreation and leisure", "handling stress and other physiological demands", "acquiring, keeping and terminating a job", and "community life".

CHAPTER 2

LITERATURE REVIEW

This literature review will provide: the definition of breathing pattern that will be evaluated in the ICF domain of body functions and structure; an overview of methods that have been used to assess breathing pattern; the definition of functional capacity that will be evaluated in the ICF domain of activity; an overview of tests that have been developed to assess functional capacity; the definition of functional performance that will be evaluated in the domain of participation; and an overview of the tests developed to assess functional performance.

BREATHING PATTERN

Definition

At rest, during quiet breathing, rib cage (RC) and abdomen (AB) move with considerable independency, accommodating different volumes. In healthy subjects, the RC and the AB displaces outward during inspiration and inward during expiration (Konno & Mead, 1967; Chihara, Kenyon & Macklem, 1996). During a respiratory cycle a volume of air is inspired and expired and the time taken for inspiration and expiration can be measured. The breathing pattern, thus, encompasses the chest wall motion and its time and volume components (Tobin, 1992).

The diaphragm descent increases the intra-abdominal pressure, which is transmitted through the zone of apposition (part of the diaphragm that is directly affixed to the ribcage) to expand the lower part of the rib cage. The increase in abdominal pressure, at the same time, results in an outward movement of the anterior abdomen wall. The diaphragmatic action depends on the size of the zone of apposition and on the

magnitude of the rise in intra-abdominal pressure. In addition, due to the insertion of the diaphragm in the lower ribs, its descent exerts a cranially oriented force on the lower ribs that has the effect of raising them and moving them outwards. For effective diaphragm action, the muscle fibers of the diaphragm must be oriented cranially, and the abdominal contents should effectively oppose diaphragm descent (D'Angelo & Sant'Ambrogio, 1974; De Troyer & Estenne, 1988).

The classic model of the chest wall considers the chest wall as two moving parts determined by two compartments: RC and AB (Konno & Mead, 1967). Body position can affect the compliance of the RC and AB compartments. During quiet breathing, in the standing posture, the AB is as compliant as the RC. In the seated position, the weight of the abdominal contents distends the abdominal wall, and consequently the compliance of AB is reduced reducing the contribution of the AB to the tidal volume. In the supine position, the compliance of the AB is increased, thus increasing its contribution to tidal volume (Agostini & Rahn, 1960).

The pattern of breathing depends on the compliance of the RC and AB compartments (Matos et al, 2012), and therefore, is influenced by different factors such as body position (Vershakelen & Demedts, 1995; Aliverti et al, 2001; Romei et al., 2010), age (Vershakelen & Demedts, 1995; Britto et al., 2005), sex (Vershakelen & Demedts, 1995; Parreira et al., 2010; Romei et al, 2010) and others (Binazzi et al., 2006; Tomich et al., 2007; Alves et al., 2008).

Breathing pattern data provides important information about respiratory movement, and is part of physiotherapy assessment of individuals with acute and chronic pulmonary disorders. In addition, measurement of respiratory rate and tidal volume (the volume of gas inspired or expired during resting breathing), also form part

of physiotherapy assessment and response to physiotherapy interventions (Vershakelen & Demedts, 1995; Britto et al., 2005; Tobin, 1992).

Methods of measurement

Visual inspection

Assessment of breathing pattern was documented as early as 1842 by counting and documenting respiratory rate (Quetelet, 1842). The clinical examination of breathing pattern is usually done by respiratory rate counting over a period from 15 to 60 seconds, observing the occurrence of abnormally deep or superficial breaths, and documenting whether the thoracic and abdominal compartments contribute equally or not to establish the pattern (Tobin, 1992; De Groote, Wantier, Chéron, Estenne & Paiva, 1997).

Although visual inspection has the merit of being simple to measure, obtained by observation and not altered by the use of any device for measurement (Benchetrit, 2000), this method provides little information and can often be inaccurate (Tobin, 1992).

It has been increasingly recognized that a more detailed analysis of the breathing pattern could provide valuable information about the respiratory system. As advances were made in the attempt to elucidate the mechanisms involved in the control of breathing pattern and chest wall motion, concomitantly improvements of the methods used to for evaluation had to be developed (Tobin, 1992; Parreira et al., 2012).

Spirometers and pneumotachometers

Spirometers and pneumotachometers enable data of volume and respiratory rate to be obtained directly. However, for accurate measurements temperature, humidity and

barometric pressure need to be known; the viscosity and density of expired gas can influence the records; the interfaces such as mouth pieces, nasal clip or facial masks used for data collection can leaks, add dead space to the tidal volume and promote reduction of respiratory rate. Also these measurement tools cannot be used for evaluation of children and non-cooperative adults, or during sleep and phonation (Tobin, 1992; Gilbert, Auschincloss, Brodsky & Boden, 1972; Aliverti & Pedoti, 2003; Aliverti, 2008).

The limitations involved in these two forms of evaluation led researches to seek alternatives for indirect measurement of lung volume by measuring the movement of the external surface of the chest wall (Konno & Mead, 1967; Levine et al., 1991).

Mercury-in-silastic strain gauges

The method consists of two rubber tubes filled with mercury that are wrapped around the chest. The mercury columns are part of a balanced Wheatstone bridge that is an assembly scheme of electrical elements that allows the measurement of an unknown electrical resistance though the amplification of the deformation of the mercury (length and width changes) that results in a pressure measurement. Variations of the electrical resistance alter the balance of the bridge and these changes are amplified and recorded. Provided that there is no change in body posture, this technique can provide an accurate measure of tidal volume (Tobin, 1992; Oliveira et al., 2010).

Magnetometers

Magnetometers measures changes in the anteroposterior diameters of rib cage and abdomen by two coils placed on both anterior and posterior chest wall. An exciter coil produces a magnetic field, by an alternating current, and another coil receives the

signal. The signals of both rib cage and abdomen are summed and provide an accurate measure of tidal volume when calibrated. Any change in body position produces alterations in anteroposterior diameters resulting in loss of calibration and measurement of an inaccurate volume (Levine et al., 1991; Tobin, 1992).

Respiratory inductive plethysmography

For a long time, respiratory inductive plethysmography has been the method used most often to noninvasively and quantitatively evaluate rib cage and abdominal motion and give measures of tidal volume, respiratory rate, among others. The measures obtained by this method are based on transverse section area captured by two inductive bands. The bands are placed around the rib cage (at the level of axilla) and abdomen (at the level of umbilicus). Two thin adhered elastic parts that surround a sinusoidal shaped transducer wire surrounded by plastic material compose the bands. The calibration of this method can be performed by different methods (Chadha et al., 1982). Limitations of this method include: the need for calibration at every change of position, need for cooperation and involvement of the subject during the calibration and the fact that the operation of this method is based on the two degrees of freedom model of the chest wall (Chadha et al., 1982; Parreira et al., 2010). Considering that the forces acting on upper rib cage are different from those acting on its lower part, the measurement of the volume change through the transverse section area of the rib cage and abdomen is limited and subject to errors (Milledge & Stoff, 1977; Chadha et al., 1982; Parreira et al., 2010).

Optoelectronic plethysmography (OEP)

The relation between motion and volume change can be evaluated by geometrical principles. Technical evolution in image processing and parallel computing allowed the analysis of the movement of several points on the body surface using an optical reflectance analysis system (Konno & Mead, 1977; Cala et al., 1996).

In this context, more recently, OEP has emerged as a valid (Cala et al., 1996; Aliverti et al., 2001), reliable (Vieira, Hoffman, Pereira, Britto & Parreira, 2013) and non-invasive method (Aliverti et al., 2001; Bianchi et al., 2007) capable of accurately providing an indirect measure of chest wall variations and its three compartments (pulmonary rib cage, abdominal rib cage and abdomen) (Cala et al., 1996). The divisions of compartments are established from anatomical features. The transverse section at xiphoid process separates the pulmonary rib cage and abdominal rib cage, and the costal margin anteriorly and the lowest point of inferior costal margin posteriorly separates the abdominal rib cage and the abdomen (Figure 4) (Ferrigno, Borghese & Pedotti, 1990).

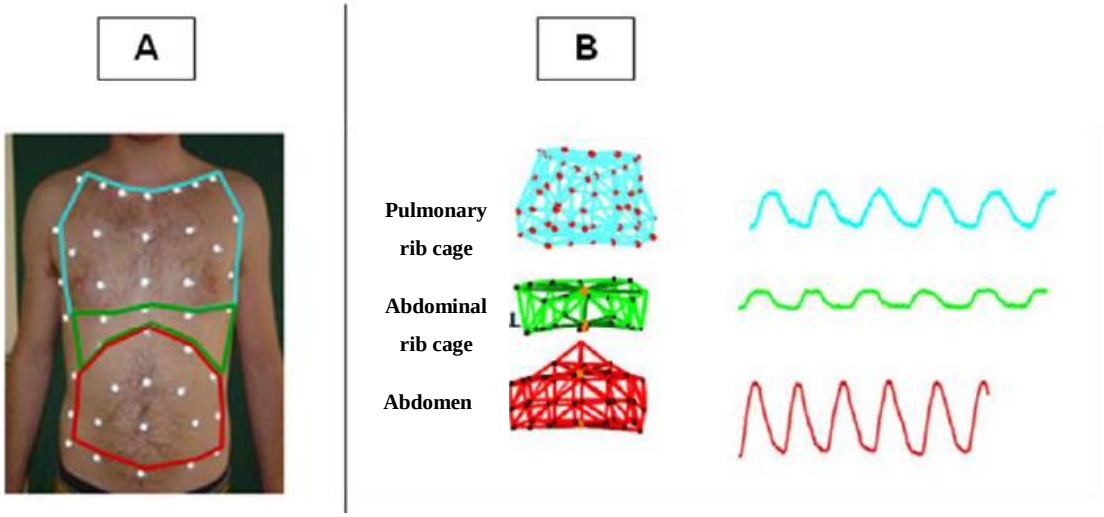


Figure 4- Three compartmental chest wall representation. A- borders of the three compartments of the chest wall in anterior view. B- geometric models and respective traces related to the volume of each compartment.
Source: Vieira, 2011, p.42.

OEP can be used in different body positions and situations (Aliverti et al., 2001; Bianchi et al., 2007); does not assume any limitation of the number of degrees of freedom of the chest wall; does not require the use of a mouthpiece, nasal clip or any other device coupled to the subject, and does not involve the cooperation of the individual during the calibration process (Aliverti et al., 2001; Aliverti & Pedotti, 2003; Aliverti, 2008).

The system is composed by eighty-nine markers and at least four cameras that emit infrared light towards the markers, which are placed at anatomical points on anterior, posterior and lateral parts of an individual's chest wall. The red light beam emitted by the flashes of the cameras is reflected by each marker and recaptured by the cameras. Therefore, OEP measures the three-dimensional positions and displacements of each point (Aliverti & Pedotti, 2003;Aliverti, 2008). The three-dimensional geometrical information is extracted from the combination of at least two-dimensional images obtained by two cameras at the same instant from different positions (Silva, 2011). Figure 5 shows the eighty-nine marker setup.

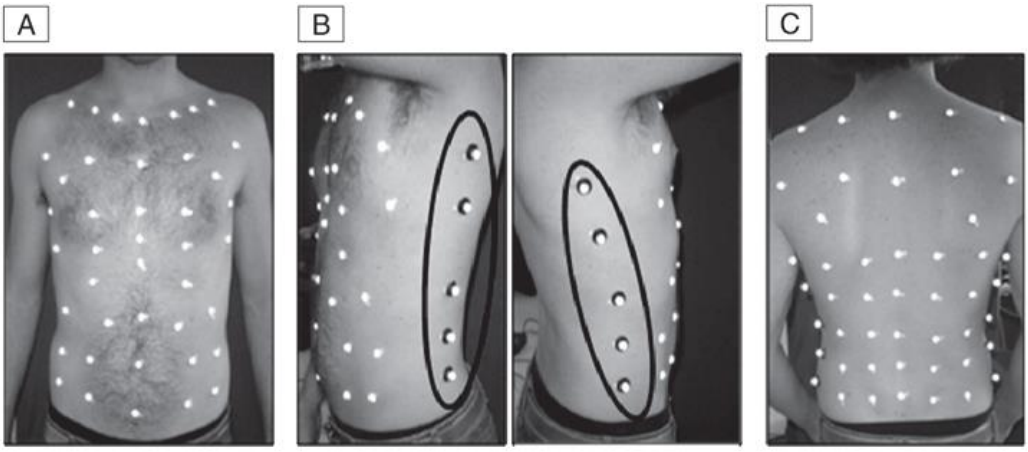


Figure 5- 89 markers set up for either seated or standing positions.
Note: 42 markers placed anteriorly (A), 10 laterally (B) and 37 posteriorly (C).
Source: Parreira et al., 2012, p.441.

For data collection in the supine position, fifty-two markers are placed (Figure 6), being 42 anterior and 10 lateral. In the supine position, for the construction of the

geometric model, a number of virtual points belonging to a fixed reference plane corresponding to the horizontal plane of the support surface are used (Aliverti et al., 2001).

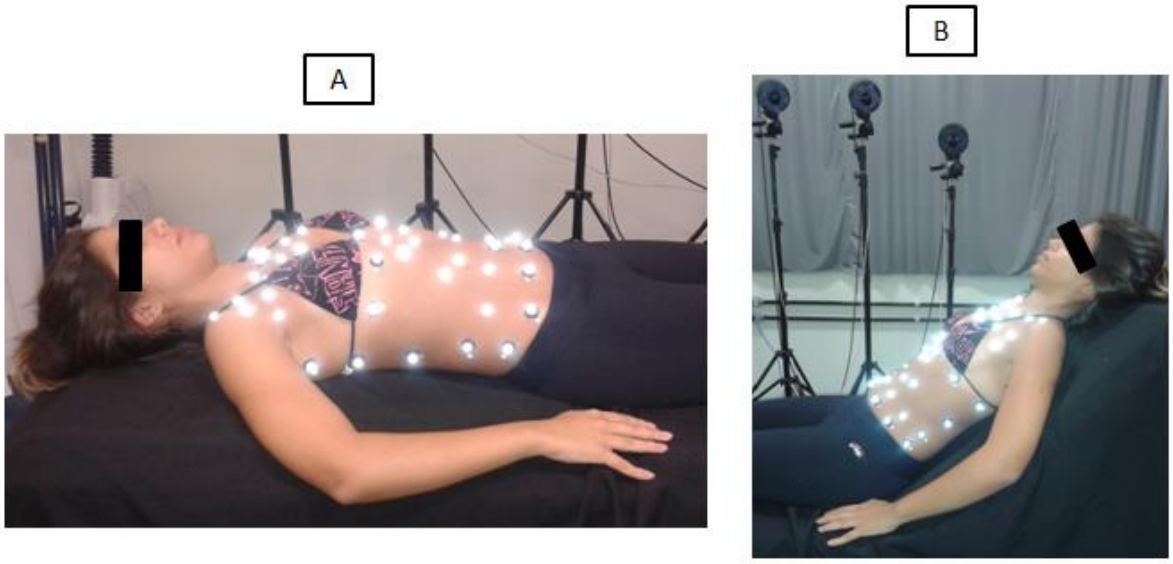


Figure 6- 52 markers set up for supine position (A) and supine position with trunk inclination of 45° (B). Source: Provided by the author.

System calibration consists of two procedures to accurately determine the three-dimensional coordinates. The first is important for optical distortion corrections and consists on the record for five seconds of a set of markers arranged on a metal piece composed of X, Y and Z axes (Figure 7 A). For data collection in orthostatic, seated and supine positions the piece is placed in the data collection area on a flat surface. For data collection made with trunk inclination, the piece is positioned in the plane and with the degree of inclination in which data collection will be done (Ferrigno et al., 1990). The second procedure is necessary for the determination of geometric parameters of the collinearity equations used in three-dimensional coordinate computation. For this, only the Y-axis is used and the metal piece should be moved in the frontal, sagittal and transverse planes during 40, 20 and 20 seconds, respectively, to cover the entire data collection area (Figure 7 B, C, and D) (Ferrigno et al., 1990).

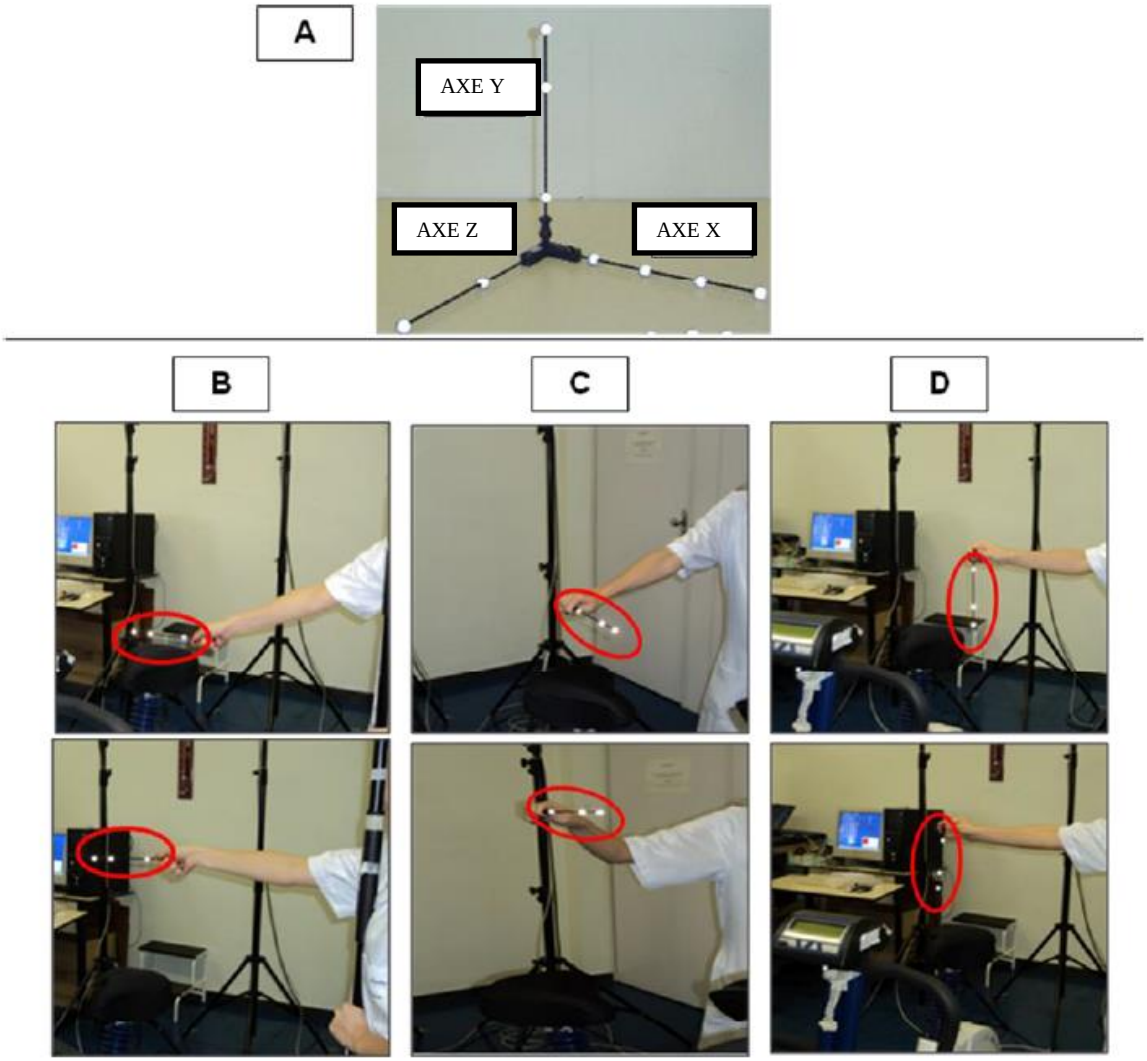


Figure 7A- Metal piece used for the first procedure of optoelectronic plethysmography calibration and its axes (X, Y, and Z). 7B, 7C, 7D- Movements performed during calibration procedure using Y-axis, highlighted in red the frontal, sagittal and transverse planes respectively.
Source: Vieira, 2011, p.40.

From the three-dimensional coordinates of each point, the volume within the chest wall section reflected by the surface markers is computed by the connection of the points to form tetrahedron triangles. A geometric model developed on the basis of the Gaussian theorem, in which the integral surface is converted into a volume integral, is then applied to determine chest wall volume (Alivert & Pedotti, 2003; Aliverti, 2008).

From the geometric chest wall model it is possible to obtain variations in volume and the contributions of each compartment (pulmonary rib cage, abdominal rib cage and abdomen) for total volume (Figure 4) (Alivert & Pedotti, 2003).

Several studies have used OEP in the assessment of healthy individuals and those with COPD, pulmonary fibrosis, upper lobectomy, patients using pressure support ventilation, hemiplegia, etc., using different experimental protocols (Parreira et al., 2012). However, up to now, reference values for the variables evaluated by this method have not been established. Considering the relevance of breathing pattern assessment and the important advantage of obtaining these variables using OEP, it is important to obtain reference values for these variables. Establishing normal values will be important for comparison and better understanding of the alterations of these variables in individuals with different respiratory impairments that may compromise respiratory function. Using OEP and having normal values for comparison will contribute to the assessment and identification of respiratory impairments. The establishment of OEP reference values will be presented in Chapter 3.

FUNCTIONAL CAPACITY

Definition

Functional capacity is the maximal capacity to achieve a functional activity in a standardised environmental (Bui et al., 2017). Functional capacity differs from exercise capacity which is the physiological maximal exercise achieved.

The assessment of exercise capacity is important to determine peak exercise level, the mechanisms for exercise limitations, the appropriate intensity of exercise training in pulmonary rehabilitation, and to evaluate the response to pulmonary rehabilitation (American Thoracic Society & American College of Chest Physicians,

2003). The cardiopulmonary exercise testing (CPET) is considered the gold standard to assess exercise capacity and can be performed on a treadmill or cycle ergometer (American Thoracic Society & American College of Chest Physicians, 2003). However, the test does not evaluate limitations in activities and it requires specific equipment and specialised staff that are not easily available in pulmonary rehabilitation programs (American Thoracic Society & American College of Chest Physicians, 2003). Therefore, non-laboratory-based field tests were developed to assess functional capacity before and after pulmonary rehabilitation programs (Holland et al., 2014). These tests of functional exercise capacity are considered representative of individuals' functional status. The choice of the most appropriate test depends on the information that is needed and the resources available. All of the functional capacity tests are simple to perform and enable standardisation of assessment.

Methods of measurement

Six-minute walk test

The six-minute walk test (6MWT) is the most commonly used test to assess functional exercise capacity (Holland et al., 2014). The 6MWT (Butland, Pang, Gross, Woodcock, & Geddes, 1982) was developed from a 12-minute walking test for people with chronic bronchitis (McGavin, Gupta & McHardy, 1976). The development of the 6MWT was to accommodate people with more severe respiratory disease for whom a 12-minute test would be considered exhausting (ATS, 2002; Butland et al., 1982; Cooper, 1968). The 6MWT is a self-paced test to measure how far a patient can walk on a flat track in 6 minutes. Standardised instructions and encouragement are given every minute. A 30 metres hallway is recommended (ATS, 2002), however circular tracks can be used and have been shown to result in greater distances walked of 13 to 19 meters

compared to a straight track (Bansal et al., 2008; Sciurba et al., 2003). The primary outcome of the test is the distance walked in a period of six minutes (Holland et al., 2014; ATS, 2002).

The 6MWT is considered a valid and reliable test (ICC= 0.88 to 0.99) (Cahalin, Pappagianopoulos, Prevost, Wain & Ginns, 1995; Sciurba et al., 2003) to measure functional exercise capacity and the response to pulmonary rehabilitation in people with COPD (Holland et al., 2014). The existence of the learning effect (improvements of 26.3 metres on the second test) (Singh et al., 2014) and the proportion of COPD individuals who walk further on the second test (50-87%) (Spencer et al., 2012; Jenkins & Cecins, 2010) justify the necessity of two 6MWTs to be performed at initial assessment. There is a moderate to strong correlation between the 6MWT and the oxygen consumption (VO_2) peak (r = 0.40 to 0.80) (Chuang, Lin, & Wasserman, 2001; Kozu et al., 2010) and between the 6MWT and peak work rate (r = 0.59 to 0.80) (Carter et al., 2003; Kozu et al., 2010) on a incremental CPET in individuals with COPD.

The relationship between the 6MWT and health-related quality of life assessed by the St George's Respiratory Questionnaire (SGRQ) in COPD individuals varies between weak and moderate (r = -0.26 to -0.56) (Brown et al., 2008; Oga et al., 2002). In addition, the 6MWT correlates moderately to strongly with objective measures of physical activity in individuals with COPD (r = 0.42 to 0.75) (Hernandes et al., 2009; Pitta et al., 2005).

The 6MWT is responsive to interventions and is commonly used to assess the effects of exercise training. The minimal important difference (MID) of the 6MWT for adult individuals with COPD undertaking exercise training is 30 metres (95%CI 25 to 33 meters) (Holland et al., 2014). According to a systematic review involving 38 randomized controlled trials (RCTs) in stable COPD individuals, pulmonary

rehabilitation compared to usual care resulted in a mean difference of 44 metres (95%CI 33 to 55) on the 6MWT (McCarthy et al., 2015). Although the 6MWT has been the most used test in pulmonary rehabilitation programs, some studies have reported that around 32 to 53% individuals did not increase the 6MWT distance after the program (Garrod, Marshall, Barley, & Jones, 2006; Vagaggini et al., 2009). This could be explained by the fact that to show improvement in the 6MWT, the individuals have to walk faster, and in fact, the pulmonary rehabilitation program is usually focused on improving endurance or the capacity of the participants to do activities for longer (Wootton et al., 2014). Therefore, the 6MWT might not register improvement.

Incremental shuttle walk test

The incremental shuttle walk test (ISWT) is used to assess peak exercise capacity of individuals with COPD (Singh et al., 2014; Holland et al., 2014). The test was developed by Singh et al (1992) based on a modification of the Shuttle run test (Singh, Morgan, Scott, Walters, & Hardman 1992). The test is incremental and consists of 12 levels and conducted on a 10metre flat course with standardised instructions and an audio signal for each level to control the participant's speed. The test is symptom-limited with a maximum duration of 12 minutes and a maximum distance walked of 1020 metres. The ISWT requires a space of 10 metres signified by two cones with 9.0 metres between them and 0.5 meters behind each cone. The space behind the cones avoids abrupt changes of direction (Figure 8) (Singh et al., 2014; Holland et al., 2014; Singh et al.,1992).

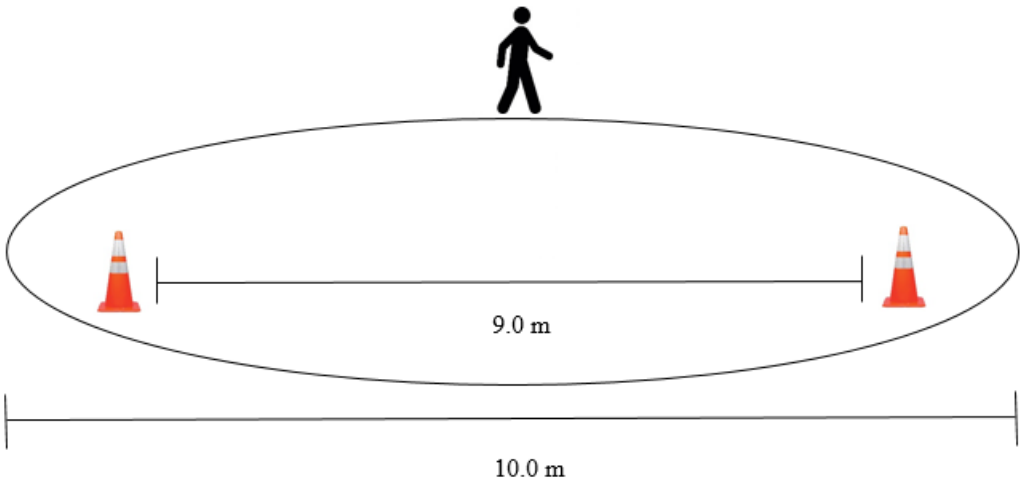


Figure 8- Representative one lap of the ISWT, where one shuttle corresponds to 10 metres.

Source: Made by the author

The first level starts with the speed 0.50 m/s and increments 0.17 m/s each minute. This increment continues for 12 minutes with the final speed being 2.37 m/s (Table 2). A triple bleep indicates the beginning of the test and the level change while a single bleep indicates the moment that the participant should be turning round the cone to proceed back down the course (Singh et al., 1992). The primary outcome of the test is distance walked (Singh et al., 2014; Holland et al., 2014). Termination of the test is when participants feel too breathless to maintain the speed; or examiner observes that participant failed to complete a shuttle in the time allowed that is when participant is more than 0.5 metre away from the cone when the bleep sounds; and achievement of 85% of the predicted heart rate derived from the formula [210 – (0.65 x age)] (Singh et al., 1992).

Table 2- Incremental shuttle walk test protocol

Level	Speed		Lap time (s)	Number of shuttles per level	Cumulative Distance (m)
	m/s	kph			
1	0.50	1.80	20.00	3	30
2	0.67	2.41	14.93	4	70
3	0.84	3.03	11.90	5	120
4	1.01	3.63	9.90	6	180
5	1.18	4.25	8.47	7	250
6	1.35	4.86	7.41	8	330
7	1.52	5.47	6.58	9	420
8	1.69	6.08	5.92	10	520
9	1.86	6.69	5.38	11	630
10	2.03	7.31	4.93	12	750
11	2.20	7.92	4.55	13	880
12	2.37	8.53	4.22	14	1020

Source: Adapted from Singh et al., 1992. kph – kilometres per hour, m/s- metres per second, s- seconds, m -metres

The ISWT has been validated as a measure of peak exercise capacity in people with COPD. The relationship between peak VO_2 or peak work rate on CPET and the ISWT distance is strong (r = 0.75 to 0.88) (Luxton, Alison, Wu, & Mackey, 2008; Arnadottir, Emter, Hedenstrom, Larsson, & Boman, 2006) with no significant differences in peak VO_2 measurements between CPET and ISWT (Hill et al., 2012a; Zainuldin, Mackey, Alison, 2012). The linear response in VO_2 to increasing work rate in both the CPET and ISWT tests suggests that the cardiopulmonary responses are similar (Hill et al., 2012a). The ISWT has been shown to be reliable (ICC = 0.88) (Campo, Chilingaryan, Berg, Paradis, & Mazer, 2006) but there is a learning effect between the two first tests of mean differences from 9 to 25 metres (Singh et al., 2014; Hill et al.,

2012a; Arnadottir et al., 2006). Therefore, two tests should be performed in the initial assessment (Singh et al., 2014; Holland et al., 2014).

There is a weak to moderate correlation (r = 0.17 to 0.58) between ISWT distance and the objectively measured level of physical activity in daily life (Dyer et al., 2013; Zwerink, van der Palen, van der Valk, Brusse-Keizer, & Effing, 2013). In addition, the relationship between the ISWT and health-related quality of life assessed by SGRQ in COPD individuals is moderate (r = -0.47 to -0.55) (Ushiki et al., 2017; Emtner, Amardottir, Hallin, Lindberg & Janson, 2007) with better correlations for activity domain (r= -0.67) (Emtner et al., 2007).

The MID for the ISWT is 47.5m (Singh, Jones, Evans, & Morgan, 2008) and a meta-analysis involving eight randomized controlled trials showed that the test is responsive to evaluate the effects of pulmonary rehabilitation compared to usual care (McCarthy et al., 2015). The mean treatment effect from 65 RCTs of pulmonary rehabilitation (3822 participants) was 40m (95%CI 22-47), which was slightly less than the MID (McCarthy et al., 2015). To show improvement in the ISWT individuals have to walk faster and while individuals after pulmonary rehabilitation may improve endurance capacity for walking, they may not be able to walk faster.

Endurance shuttle walk test

The endurance shuttle walk test (ESWT) is used to assess endurance functional capacity (Holland et al, 2014). The test was developed in 1999 and is performed on the same course as the ISWT, and is externally paced (Revill, Morgan, Singh, Williams, & Hardman, 1999). However, the test is not incremental and is conducted at a constant speed. The protocol of the ESWT is presented on Table 3. The test starts with a warm up period of 100 seconds of walking at a slow pace, and, after that there are

standardised instructions advising that at the next beep the walking speed will increase to the speed that should be kept over the test (Holland et al., 2014). The speed for the ESWT is determined from the ISWT. While the original method for calculating the speed for the ESWT was based on estimating the speed equivalent to 85% of the calculated peak VO_2 of the ISWT (Revill et al., 1999), recent studies have proposed simpler methods. Hill et al, 2012b, evaluated a speed equivalent to 85% of the maximum speed achieved in the ISWT as appropriate (Hill et al., 2012b). More recently, an alternative method for calculation of the speed for the ESWT was proposed from the distance walked in the 6MWT (6MWD) (Wootton et al., 2014), in order to circumvent performing the ISWT. The equation developed was: ESWT speed = 0.4889 + (0.0083 x 6MWD). This alternative method of calculating the speed for the ESWT from the 6MWD may be useful for clinicians who do not use the ISWT but use the 6MWT at initial assessment (Wootton et al., 2014).

Table 3- Endurance shuttle walk test protocol

Level	**Warm up speed**		**Endurance speed**		**Shuttle time (s)**
	m/s	kph	m/s	kph	
1	0.42	1.50	0.49	1.78	20.30
2	0.42	1.50	0.58	2.09	17.30
3	0.42	1.50	0.68	2.44	14.80
4	0.42	1.50	0.76	2.72	13.30
5	0.42	1.50	0.83	3.00	12.00
6	0.67	2.40	0.91	3.27	11.00
7	0.67	2.40	1.00	3.60	10.00
8	0.67	2.40	1.05	3.79	9.50

9	0.67	2.40	1.14	4.11	8.80
10	0.67	2.40	1.21	4.36	8.30
11	0.67	2.40	1.29	4.65	7.80
12	0.67	2.40	1.38	4.97	7.30
13	0.67	2.40	1.43	5.14	7.00
14	0.67	2.40	1.54	5.54	6.50
15	0.67	2.40	1.60	5.76	6.30
16	0.67	2.40	1.67	6.00	6.00

Source: Adapted from Revill et al., 1999. kph – kilometres per hour, m/s- metres per second, s- seconds.

There are no studies, which have assessed the validity of the ESWT compared with laboratory-based exercise tests (Singh et al., 2014). Hill et al. demonstrated that the VO_2 peak and heart rate peak achieved during a CPET and an ESWT were similar (Hill et al., 2012a). The ESWT has appropriate reliability with no differences observed between two tests performed on the same day. Therefore, two tests do not appear to be necessary when the ISWT was performed before the ESWT (Singh et al., 2014; McKeough, Leung, & Alison, 2011; Revill et al., 1999).

ESWT correlates moderately with objective measures of physical activity (steps/day) in individuals with COPD ($r = 0.44$) (Zwerink et al., 2013). No studies, were found which assessed the relationship between the ESWT and any measure of health-related quality of life.

While no study has published a definitive MID for the ESWT, the MID proposed for the ESWT after pulmonary rehabilitations is 186 seconds or 203 metres (Holland et al., 2014). The responsiveness of the ESWT to change is moderate to high with standardised response means (mean change/standard deviation of change) ranging from 0.52 to 1.27 (Holland et al., 2014; Singh et al., 2014).

The ESWT seems to be a more responsive measure of pulmonary rehabilitation effects than the ISWT or 6MWT (Eaton et al., 2006; Revill et al., 1999). An improvement of 160% in ESWT distance was observed after a seven-week pulmonary rehabilitation program compared to a 32% improvement in ISWT (Revill et al., 1999). In addition, an improvement of 92% or 302 metres in ESWT was observed after an eight-week program compared to 17% improvement in 6MWT distance (Eaton et al.,2006). Usually, after a pulmonary rehabilitation program the individuals may not be able to improve the speed with which they perform activities, but may be able to perform activities for longer. Therefore, the ESWT seems to be a better measure to show the effects of pulmonary rehabilitation on functional exercise capacity.

The 6MWT, ISWT and ESWT are called field walking tests and assess walking capacity only, but do not include the assessment of upper limb activities which are also important for daily functional tasks.

Glittre-ADL test

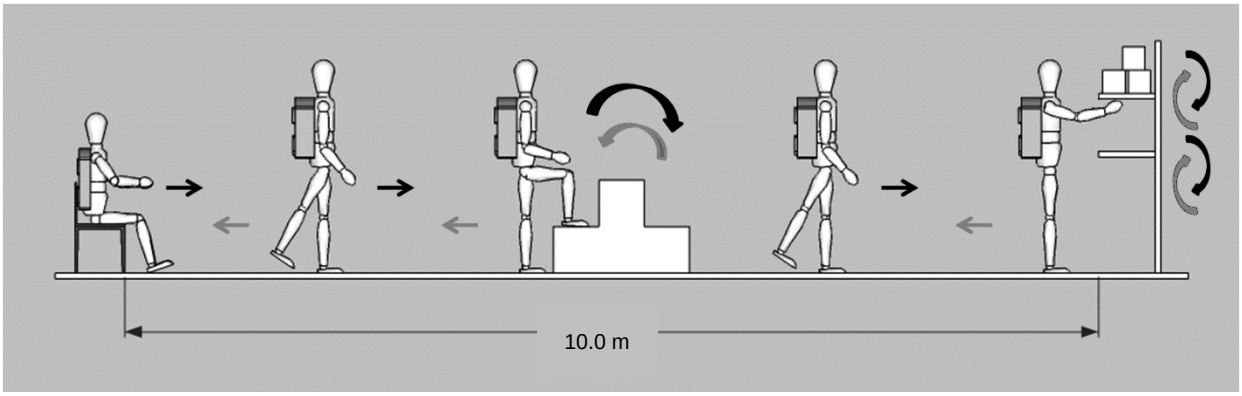
The Glittre-ADL test has been developed as a test to assess functional capacity for everyday tasks as it includes multiple tasks of standing from a chair, walking, climbing stairs and a grocery-shelving task (Figure 9) (Skumlien, Hagelund, BjØrtuft, & Ryg, 2006). These activities were chosen to represent common tasks of everyday life (Skumlien et al., 2006).

In the Glittre-ADL test the patient stands up from the chair and walks along a flat 10 metre course. In the middle of the course the patient has to walk getting up and down the two steps. At the end of the 10 metres there is a shelving task which requires the patient to move three weights of 1.0 kg each (one by one) from the top shelf to the bottom shelf and down to the floor. After that they have to move the weights back to the

bottom shelf and to the top shelf again. Then, they have to turn and walk back over the steps and sit down and then immediately start the next lap. During the test, individuals wear a backpack filled with 2.5 kg for women or 5.0 kg for men. Each step of the stairs is 17 cm high and 27 cm deep. For the shelving task, the two shelves are adjusted so that one is at the level of the shoulder and the other at the waist for each patient. The test consists of five laps and the individuals are asked to complete the test as fast as possible (Skumlien et al., 2006).

The primary outcome of the test is the time taken to complete five laps. The individuals are allowed to stop and rest during the test, but they are instructed to resume the test as soon as possible (Skumlien et al., 2006).

Figure 9 - Representative one lap of the Glittre-ADL test (i.e. one lap is from sitting in the chair to back to sitting in the chair)



Source: Adapted from Fernandes-Andrade, Britto, Soares, Velloso, & Pereira, 2017.

The weight of the backpack that the individuals wear during the test (2.5 kg for women and 5.0 kg for men) was designed to simulate the weight of supplementary oxygen equipment (i.e. 2.5kg), which can be exchanged for the oxygen cylinder when appropriate. In order to standardise the test time for genders, the authors doubled the weight for men (Skumlien et al., 2006). However, further investigation on this method

of correcting for gender differences needs to be investigated (Dechman & Scherer, 2008). In addition, in clinical practice it is not common to see individuals carrying backpacks or oxygen in backpacks. Moreover, recent studies have noted deficits in balance and coordination in people with COPD, thus the backpack may impair participants capacity during the test (Oliveira et al., 2017; Butcher, Meshke & Sheppard, 2004). The Glittre-ADL test without the backpack will be evaluated in Chapter 4.

There was a strong association between the Glittre-ADL test time and the 6MWD in individuals with COPD (r = -0.82) (Skumlien et al., 2006), which suggests that the test has content validity. As no gold standard exists for functional capacity, the 6MWT was used as the comparison. The physiological responses of the Glittre-ADL test in individuals with COPD have been evaluated in three studies (Karloh, Karsten, Pissaia, de Araujo, & Mayer, 2014; Tufanin et al., 2014; Souza et al., 2016). The Glittre-ADL test induced a slightly higher peak VO_2 compared to the 6MWT (18.1 ± 3.3 vs 17.0 ± 3.86 $ml.kg^{-1}.min^{-1}$, p = 0.04), however there was a strong correlation between peak VO_2 for both tests (r = 0.87) (Karloh et al., 2014). Tufanin et al (2014) compared the VO_2 at the end of two Glittre-ADL tests with the peak value reached on an incremental CPET. The results showed that the VO_2 reached in the end of the Glittre-ADL test was approximately 90% of the peak value on the incremental CPET (Tufanin et al., 2014). Both studies observed a stabilization of the cardiac, ventilatory and metabolic variables after the third lap of the Glittre-ADL test (Karloh et al., 2014; Tufanin et al., 2014). The Glittre-ADL test in a shorter number of laps will be evaluated in Chapter 5. Souza et al (2017) evaluated the ability of the Glittre-ADL test to discriminate disease severity (mild to severe) in people with COPD. The findings showed that the energy expenditure (VO_2) required for participants were similar,

irrespective of disease severity, however, the VO_2 of the Glittre-ADL test in relation to VO_2 peak obtained by CPET, was significantly higher in the severe COPD than mild and moderate COPD (Souza et al, 2016).

The reliability of the Glittre-ADL test was evaluated and considered appropriate (r = 0.93) with a learning effect varying from 6-7% (dos Santos et al., 2016; Skumlien et al., 2006) to 17% (Jose & Dal Corso, 2015). Therefore, two tests should be conducted at the initial assessment (Skumlien et al., 2006).

The Glittre-ADL test time was compared with health-related quality of life assessed by the SGRQ and the Pulmonary Functional Status and Dyspnoea Questionnaire (PFSDQ) in people with COPD Moderate correlation was shown between the subscale of Activity in the SGRQ ($SGRQ_{act}$) (which are activities that cause or are limited by breathlessness) and the Glittre-ADL test (r = 0.43); and a weak correlation between the dyspnoea subscale of the PFSDQ ($PFSDQ_{dys}$) and the Glittre-ADL test (r = 0.30) and between a general assessment of most day-to-day activities ($PFSDQ_6$) and the Glittre-ADL test) (r = 0.35) (Dechman & Scherer, 2008; Skumlien et al., 2006). The magnitude of the correlations did not exceed those observed for the 6MWT with health-related quality of life (Brown et al., 2008; Oga et al., 2002). The Glittre-ADL test time was also correlated with the domain activity of the London Chest Activity of Daily Living (LCADL) scale (r = 0.67). (Correa, Karloh, Martins, dos Santos & Mayer, 2011).

Only one study evaluated the correlation of the Glittre-ADL test time with objective measures of physical activity in people with COPD. Using an accelerometer for 12 hours on two consecutive weekdays Karloh et al (2014) observed correlations varying from r= -0.33 for total energy expenditure to r= -0.66 for walking movement intensity (Karloh et al., 2014).

The MID for Glittre-ADL test after 24 sessions of pulmonary rehabilitation in individuals with COPD is 0.38 minutes (Gulart et al., 2018). The responsiveness of the test to exercise intervention was assessed after a 4-week inpatient pulmonary rehabilitation program (Skumilien et al., 2006) and after a 12-week supervised exercise program in primary care (Skumlien, Aure Skogedal, Skrede Ryg & BjØrtuft, 2008). Skumlien et al (2006) showed a 0.89 minute reduction (95%CI = -0.48 to -1.30) in Glittre-ADL test time after pulmonary rehabilitation [a shorter test time is an improvement]. Skumlien et al (2008), however, did not observe a difference in the Glittre-ADL test time after 12-weeks of resistance or endurance exercise training in primary care. The participants in the study in primary care were the same as those in the 4-week program and the authors have suggested that a ceiling effect for change in the Glittre-ADL test time may have occurred after the 4-week program.

While the Glittre ADL-test seems to be a good measure of functional daily exercise capacity as it includes upper limb activities which are known to reduce ventilatory capacity when the arms are elevated and increase dyspnoea in this population (Velloso, Stella, Cendon, Silva & Jardim, 2003; McKeough, Alison & Bye, 2003); the test has the same limitation of the 6MWT and ISWT, since for an improvement, the individuals have to perform the test faster. In this context, a modification on Glittre-ADL test, to evaluate endurance capacity may be appropriate. The development of a Glittre endurance test may contribute to the identification of limitations in the patient's endurance for daily activities and be more responsive to improvements after pulmonary rehabilitation. The development of a Glittre Endurance test is presented in Chapter 6.

FUNCTIONAL PERFORMANCE

Definition

Functional performance is a measure of what an individual actually does in daily life (Spruit et al., 2013), which does not necessarily require a person to use their maximal potential exercise capacity (Bui et al., 2017).

Functional performance should be evaluated in non-laboratory conditions to represent the real ability of an individual to perform activities in real-life situations. Evaluation of functional performance can be made by direct observation in individuals' real environmental, by questionnaires or using technologies such as pedometers and activity monitors to measure duration, frequency and intensity of physical activities (Bui et al., 2017).

Methods of measurement

Pedometers

Pedometers are small, portable and simple devices that measure the number of steps. They were designed to capture vertical movements, thus they may underestimate steps taken in low speed gait or might overestimate as any movement in vertical plane, such as get up from a chair, may be recorded as a step (Pitta et al., 2006; Torres-Castro et-al, 2017).

The number of steps per day is considered a measure of physical activity and is one of the strongest predictors of mortality in COPD (Waschiki et al., 2011). Lower step count is related to acute exacerbations (Moy, Teylan, Weston, Gangnon & Garshick, 2013), hospitalization (Durheim et al., 2015), dyspnoea, and reduced health-related quality of life in these individuals (Gimeno-Santos et al., 2014). Pedometers can be used as a motivational tool to encourage physical activity with the aim to reach the

recommended 10,000 steps per day suggested for health promotion (Pitta et al., 2006; Iwane et al., 2000; Torres-Castro et-al., 2017).

Some devices can estimate walking distance and energy expenditure from the number of steps per day, however, the accuracy of such estimates is low (Schneider, Crouter, Lukijic & Bassett, 2003). As individuals with COPD often have slow gait speed, the use of pedometers in this population is limited (Nolan et al., 2018).

Accelerometers

Accelerometers detect body acceleration, thus, these devices can be used to count number of steps, to quantify activity counts, to estimate time spent in activities, to classify intensity of movements and to calculate energy expenditure (Pitta et al., 2006). Accelerometers can be uniaxial, biaxial, and tri-axial detecting acceleration in one, two, and three axes, respectively. Uniaxial accelerometers are similar to pedometers, but also capture acceleration instead of only steps. As most movements occur in more than one plane, bi and tri-axial devices are more accurate than uniaxial devices (Watz et al., 2014; Torres-Castro et-al, 2017).

The number of hours and days that an accelerometer is worn and the disease severity influences the reliability of the measurement. To assess GOLD stage I individuals, 5 days of measurement are required while to assess GOLD stage IV individuals, 2 to 3 days seems to be sufficient (Watz et al., 2009). On the other hand, to demonstrate the effect of pulmonary rehabilitation on physical activity, 4 days of measurement for at least 8 hours per day are required (Demeyer et al., 2014).

The multi-axial devices, SenseWear Armband (BodyMedia, Inc., Pittsburgh, Pennsylvania, USA), DynaPort MiniMod (McRoberts BV, Hague, Netherlands), and the Actigraph GT3X (Actigraph, Pensacola, Florida, United States of America), are the

most valid and sensitive monitors for measuring physical activity in individuals with COPD (Remoortel et al., 2012).

The SenseWear Armband consists of an 8.5 x 5.3 x 2.0 cm monitor, weighting 150 grams containing a biaxial accelerometer, an USB connection, and raw data storage on the device itself. The monitor requires one AAA battery and is attached on the back of the upper right arm, touching the skin and held in place by an adjustable strap. (2018, December 25) Retrieved from: https://fccid.io/PV8-909901G01REVD/User-Manual/User-Manual-180503. The DynaPort consists of an 8.5 x 5.8 x 1.2 cm case, weighting 47 grams containing a tri-axial accelerometer, a rechargeable battery, an USB connection, and raw data storage on a MicroSD card. The device is attached to an elastic strap and positioned at the height of the second lumbar vertebra (2018, December 25) (Retrieved from: https://www.mcroberts.nl/old/products/movemonitor/dynaport). The Actigraph GT3X is the smaller and lighter than either the SenseWear armband or the Dynaport, and consists of a 4.6 x 3.3 x 1.5 cm case, weighting 19 grams. The case contains a tri-axial accelerometer, a rechargeable battery, an USB connection, a Bluetooth connection, and raw data storage inside the device itself. The device is attached to elastic strap and can be positioned at the wrist, waist, ankle, or thigh. The battery lasts 25 days and the device has 180 days of memory under continuous use (2018, December 25) (Retrieved from: https://www.actigraphcorp.com/actigraph-wgt3x-bt/). None of the activity monitors is waterproof and individuals are asked to take the device off for showering or any water activities and to reposition it correctly afterwards.

Recently, the Axivity AX3 (Axivity, Newcastle, United Kingdom) monitor has been evaluated in people with COPD (ref). The device is small 2.3 x 3.2 x 0.8 cm, and is half the weight of the Actigraph (11g), has a tri-axial accelerometer, a rechargeable

battery, an USB connection, and raw data storage. Axivity AX3 can be attached directly to individual's skin using bands or straps on different parts of the body including wrist, waist, arm, thigh, ankle, upper and lower back, and etc. The battery lasts 30 days and the device has 14 days of memory under continuous use (2018, December 25) (Retrieved from: https://axivity.com/userguides/ax3/).

The monitor has the important advantage of being waterproof, enabling, the assessment of individuals during showering which is an activity known to be difficult for COPD individuals (Velloso & Jardim, 2006). Since the Axivity does not need to be removed during data collection, it is not subject to the patient forgetting to put it back on or positioning it incorrectly.

The validity and reliability of the Axivity monitor has been evaluated in young adults and the healthy elderly (Godfrey, Barry, Mathers & Rochester, 2014), in post stroke individuals (Moore et al., 2017) and in older adults with functional impairment (Clarke et al., 2017), suggesting that the monitor is a valid and reliable tool. In addition, the Axivity AX3 has been shown to be more accurate to measure number of steps at lower speeds compared with the accelerometers Opal and Actigraph (Feng, Wong, Janeja, Kuber & Mentis, 2017).

While the Axivity seems to have advantages over other activity monitors, no study to date has reported using this device for the assessment of physical activity in COPD individuals. The study in Chapter 7 uses the Axivity monitor to evaluate the number of steps per day of the participants. Steps per day measured by the Axivity will be correlated with functional capacity evaluated by the Glittre tests to determine how representative the tests are of daily activities.

CHAPTER 3

OPTOELECTRONIC PLETHYSMOGRAPHY: REFERENCE VALUES FOR BREATHING PATTERN IN HEALTHY INDIVIDUALS DURING QUIET BREATHING

INTRODUCTION

Breathing pattern compasses the chest wall motion and its time and volume components (Tobin, 1992). In healthy subjects, during quiet breathing, it is expected that rib cage (RC) and abdomen (AB) move outward during inspiration and inward during expiration accommodating different volumes (Konno & Mead, 1967; Chihara et al., 1996). Therefore, in each respiratory cycle a volume of air is inspired and expired generating the gas flow and the time taken for inspiration (Ti) and expiration (Te) can be measured (Tobin, 1992).

During quiet breathing in the standing posture, the AB is as compliant as the RC. In the seated position, the weight of the abdominal contents distends the abdominal wall, and consequently the elastance of the diaphragm and the abdomen becomes larger, reducing the contribution of the AB to the tidal volume. In the supine position, the compliance of the AB is larger, thus increasing its contribution for tidal volume (Agostini & Rahn, 1960).

The pattern of breathing, thus, depends of compartments compliance (Matos et al., 2012), and therefore, is influenced by different factors such as position (Verschakelen & Demedts, 1995; Aliverti et al., 2001; Romei et al., 2010), age (Verschakelen & Demedts, 1995; Britto et al., 2005), sex (Vershakelen & Demedts, 1995; Parreira et al., 2010; Romei et al., 2010) and others (Binazzi et al., 2006; Tomich et al., 2007; Alves et al., 2008).

Chest wall motion assessment as well as measurement of respiratory rate and tidal volume are important part of physiotherapy evaluation of individuals with acute and chronic pulmonary disorders. Besides, the effects of physiotherapy interventions on these parameters should also be considered (Verschakelen & Demedts, 1995; Britto et al., 2005; Tobin, 1992).

For these reasons, sequentially improvements in instrumentation used for the evaluation of breathing pattern parameters have been made (Tobin, 1992; Parreira et al., 2012). In this context, the optoelectronic plethysmography, has been proposed as a noninvasive (Aliverti et al, 2001), valid (Aliverti et al., 2001), and reliable (Vieira et al., 2013) method to accurately assess breathing pattern including chest wall motion and its three compartments in different positions and situations (Aliverti et al., 2001; Parreira et al., 2012). The optoelectronic plethysmography does not assume any limitation of the number of degrees of freedom of the chest wall enabling a more detailed study of the volumes in the different compartments of the chest wall, as well as the evaluations of end-inspiratory and end-expiratory volumes, which are other differentials of this technique (Aliverti et al., 2001; Parreira et al., 2012).

Despite being frequently used in different studies in different health conditions, reference values for the parameters provided by the OEP have not been provided so far. Therefore, the primary objective of this study was to establish reference values for breathing pattern measured by OEP of healthy individuals during quiet breathing in three different postures: seated, supine, and inclined (with 45° of trunk inclination – frequently used in hospitals) using optoelectronic plethysmography. The secondary aim was to evaluate the influence of sex on breathing pattern parameters.

METHODS

Design and Sample

This was a multicenter cross-sectional study involving research laboratories from three universities. Inclusion criteria were age between 20 and 99 years, body mass index between 18.5 and 35 kg/m^2 (WHO, 2014), normal lung function according to predicted values (Pereira, Sato & Rodrigues, 2007), self-reported absence of cardiac or neuromuscular diseases, and preserved cognitive function assessed by the Mini-Mental State Examination (MMSE) (Bertolucci, Brucki, Campacci & Yara, 1994). The exclusion criteria were the inability to understand and/or perform any of the data collection. The study was approved by the Ethics Committee (ETIC 0194.0.2036000-11) of the three centres, and all participants signed a written consent form.

Main measurement instrument

Optoelectronic plethysmography (*BTS Bioenginneering*, Milan, Italy) is a valid (Cala et al., 1996; Vogiatzis et al., 2005) and reliable (Vieira et al., 2013) method capable of evaluating breathing pattern by means of indirect measurement of chest wall and its compartments: pulmonary rib cage (RCp), abdominal rib cage (RCa), and abdomen (Aliverti & Pedotti, 2003). The system consists of at least four cameras that emit infrared light toward markers attached at specific anatomical points on the individual's chest wall. The infrared rays are reflected by markers positioned on different points of the chest wall and recaptured by the cameras, generating three-dimensional coordinates that allow calculation of chest wall and its compartments volumes (Parreira et al., 2012), among other variables. For data collection performed in the seated and standing position, 89 markers are used, and for data collection in the supine or inclined position (with 45° trunk inclination), 52 markers are attached. Technical details including marker positions, data acquisition, and calibration processes

were previously published (Parreira et al., 2012).

Procedures

Data were collected in one or two days, based on the availability of the participants. Initially, participants received information about data collection, and after signed written consent form, clinical and demographic data were registered. The participants then answered the MMSE. After blood pressure, respiratory rate, heart rate, and peripheral oxygen saturation (SpO_2) (Ohmeda TuffSat, Finland) monitoring, the participants performed spirometry to lung function assessment (Koko®, PFT type; nSpireHealth Inc., CO, USA). The test was performed according to the recommendations of the American Thoracic Society (Culver et al., 2017), and the values were compared to normative data (Pereira et al., 2007). Next, the participants answered the Human Activity Profile (Souza et al., 2017) to register their physical activity level. Both spirometry and the questionnaires were administered by trained assessors.

Next, the examiner placed 89 markers on the participants' anterior, posterior and lateral chest wall, for data collection in seated position (Aliverti & Pedoti, 2003, Parreira et al., 2012). Then, posterior markers were removed and participants were positioned for data collection firstly in supine position, and then, in inclined position. Quiet breathing - defined as the participants' own breathing pattern - was assessed for 5 minutes in each of the three positions. Breathing pattern was registered for 5 minutes in seated position, followed by 5 minutes in supine and 5 minutes in inclined positions. Calibration of OEP according to the established protocols was performed before changing each position (Aliverti et al., 2001; Parreira et al., 2012).

Variables analysed

The following variables were analysed. For volume variables, we assessed chest

wall tidal volume (V_{cw}), pulmonary rib cage tidal volume (V_{RCp}), abdominal rib cage tidal volume (V_{RCa}), abdomen tidal volume (V_{AB}), end-inspiratory chest wall volume (Vei_{cw}), end-inspiratory pulmonary rib cage volume (Vei_{RCp}), end-inspiratory abdominal rib cage volume (Vei_{RCa}), end-inspiratory abdomen volume (Vei_{AB}), end-expiratory chest wall volume (Vee_{cw}), end-expiratory pulmonary rib cage volume (Vee_{RCp}), end-expiratory abdominal rib cage volume (Vee_{RCa}), and end-expiratory abdomen volume (Vee_{AB}). The relative volumes were calculated as percentage contributions: pulmonary rib cage percentage contribution ($V_{RCp\%}$), abdominal rib cage percentage contribution ($V_{RCa\%}$), and abdomen percentage contribution ($V_{AB\%}$). For time variables, inspiratory time (Ti), expiratory time (Te), total time of respiratory cycle (Ttot), and duty cycle (Ti/Ttot) were assessed. Respiratory rate (RR) and minute ventilation (product of respiratory rate and tidal volume), mean inspiratory flow (V_{cw}/Ti), and mean expiratory flow (V_{cw}/Te) were also calculated. A detailed description about the variables has been previously published (Parreira et al., 2012).

Data reduction

To determine breathing pattern variables, the middle 100 seconds from the 5 minutes registered for the quiet breathing were used.

Statistical analysis

Sample size calculation was based on the National Committee for Clinical Laboratory Standards procedure for reference interval determination that recommends that the sample size consists at least of 120 individuals (Horn & Pesce, 2003).

Data normality was verified by the Shapiro-Wilk test. Data were presented as measures of central tendency and dispersion, 95% CI, and upper and lower limit of normality (Geffreé et al., 2009). The comparisons between genders were performed by Student *t* test for independent samples, and Mann-Whitney or chi-square test, according

to the characteristic and/or variable distribution. For breathing pattern analyses participants were divided according to age initially in seven groups: 20 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years, 60 to 69 years, 70 to 79 years and 80 years and above, and also in two sub-groups according to gender The level of significance was set at 5%, and the SPSS version 15.0 was used for these analyses.

RESULTS

Participant characteristics

The flow chart of study participants' selection in each centre is presented in Figure 1. One hundred and sixty-eight participants were recruited and completed the protocol of the study. Table 1 presents demographic, anthropometric, spirometric, and clinical data of the participants. Males and females were similar for most characteristics, except age and activity level.

The number of participants in each age range separated by sex was: 20 to 29 years: 19 men and 17 women, 30 to 39 years: 16 men and 16 women, 40 to 49 years: 6 men and 17 women, 50 to 59 years: 6 men and 11 women, 60 to 69 years: 9 men and 18 women, 70 to 79 years: 3 men and 15 women, and above 80 years: 2 men and 13 women. Due to the lower number of men in the last two age ranges, participants were grouped in five groups: 20 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years, and 60 and above.

Breathing pattern reference values for adults and elderlies in seated position

Table 2 and show the reference values for males and females for each ten-year increment in age for individuals aged from 20 to 59 years, and for those aged 60 years and above in seated position. A significantly higher V_{cw} was observed for men

compared with women in all age ranges, except from 40 to 49 years and 50 to 59 years. V_{RCp}, V_{RCa} and V_{AB} were significantly higher for men compared with women for the age ranges from 30 to 39 years, 20 to 29 years and 30 to 39 years, and 20 to 29 years, 30 to 39 years and 60 and above, respectively. Women from 20 to 29 years, 30 to 39 years, and elderlies presented a significantly higher $V_{RCp\%}$ compared with men. Men presented significantly higher $V_{RCa\%}$ and $V_{AB\%}$ for the ranges from 20 to 29 years and 60 and above, respectively, compared with women. Women from 20 to 29 years, 30 to 39 years, and elderlies presented a significantly lower VE compared with men. The only difference observed between sexes for Ti occurred in the age range from 30 to 39 years, where men took longer time to perform inspiration compared with women. Similar pattern was observed for Ti/Ttot.

The end-inspiratory and expiratory volumes of the total chest all and its three compartments were significantly higher for men from 20 to 29 years, 30 to 39 years, and 40 to 49 years, compared with women, except for Vee_{RCa} in the latest age range. The Vei_{RCa} and Vee_{RCa} were also significantly higher for elderly men. V_{cw}/Ti and V_{cw}/Te were significantly lower for women from 20 to 29 years and elderlies. V_{cw}/Te were also significantly lower for women from 30 to 39 years.

Breathing pattern reference values for adults and elderlies in 45° of trunk inclination position

Tables 3 show the reference values for adults and elderlies in 45° of trunk inclination position. V_{cw} was significantly higher for men compared with women in adults from 20-29 and 30-39 age ranges. The contribution of abdominal rib cage and abdomen compartments were significantly higher in men from 20 to 29 years. $V_{AB\%}$ was also higher in elderlies and men from 40 to 49 years. Women from 20 to 29 years, and 30 to 39 years presented a significantly lower VE compared with men.

Men from 20 to 29 years presented higher end-inspiratory and expiratory volumes of the total chest wall and its two lower compartments compared with women. Similar results were observed in men at 30 to 39 years, except for end-inspiratory total chest wall volume. Elderly men presented higher end-inspiratory and expiratory volumes of the upper compartment compared with women. V_{cw}/Ti and V_{cw}/Te were significantly lower for women from 40 to 49 years and women from 20 to 29 years, 30 to 39 years, and elderlies, respectively.

Breathing pattern reference values for adults and elderlies in supine position

The reference values for males and females for each ten-year increment in age for individuals aged from 20 to 59 years, and for those aged 60 years and above in supine position are presented in table 4. A significantly higher V_{cw} was observed for men compared with women from 20 to 29, 30 to 39 and for 50-59-age range. Higher volumes for men compared to women were also observed for RCa and abdomen compartments for 20 to 29 years age range and for RCp and abdomen for 30 to 39. Elderly women in supine presented significantly higher RR compared with men. VE in the youngest age range and elderly women were significantly lower compared with men. Men from 50 to 59 years took longer time to perform inspiration compared with women.

The end-inspiratory and expiratory volumes of the total chest all and its RCa and abdomen compartments in women from 20 to 29 and 30 to 39 years were significantly lower compared with men. The Vei_{RCp} and Vee_{RCp} were also significantly lower in elderly women and women from 30 to 39 years compared with men. Moreover, Vei_{RCa} and Vee_{RCa} were also were significantly lower for elderly women. V_{cw}/Ti and V_{cw}/Te were significantly lower for women from 20 to 29 and 30 to 39 years. V_{cw}/Te were also significantly lower for elderly women.

DISCUSSION

This study presented reference values for breathing pattern variables obtained by optoelectronic plethysmography in healthy Brazilian individuals during quiet breathing for three different positions: seated, supine with 45° of trunk inclination and supine.

To the best of our knowledge this is the first study to propose reference values for all variables evaluated by optoelectronic plethysmography. In addition, this study had a multicenter design, and therefore, has a sample composed by individuals from different regions of Brazil.

Individuals from 21 to 91 years, being 60% adults and 40% elderlies, composed the sample. According to the Brazilian Institute of Geography and Statistics the number of adults and elderlies in Brazil represents on average 56.8% and 14.6%, respectively of the population from Brazil (IBGE, 2017). The higher proportion of adults in the sample, therefore, might reflect the distribution of this population in the country, contributing for the external validity.

It is known that breathing pattern is influenced by posture and sex (Vershakelen & Demedts, 1995; Parreira et al., 2010; Romei et al, 2010). The effect of posture was extensively studied being well known that the rib cage contribution to tidal volume is greater in vertical positions, while the abdomen contribution is greater in horizontal positions (Vershakelen & Demedts, 1995; Romei et al, 2010). For this reason, this study suggests reference values for breathing pattern during quiet breathing in three different positions, assuming that the values will change dependent on the posture evaluated.

Different from the effect of posture, the influence of sex has been less investigated and is still controversial (Vershakelen & Demedts, 1995; Parreira et al., 2010). Lower tidal volumes and minute ventilation were observed in women compared with men (Parreira et al., 2010; Romei et al, 2010), however, there is no consensus

regarding the influence of sex on chest wall motion. While some authors (Fugl-Meyer, 1974; Romei et al., 2010) report greater rib cage contribution in women, others observed similar contributions (Vershakelen & Demedts, 1995; Parreira et al., 2010). Therefore, this study also investigated the influence of sex on breathing pattern variables.

Despite the physiological and structural changes (Chan & Welsh, 1988; Zaugg & Lucchinetti, 2000) that occur in respiratory system as a result of aging, the literature suggests that age does not influence the breathing pattern of healthy individuals during quiet breathing (Vershakelen & Demedts, 1995; Britto, Zampa, de Oliveira, Prado & Parreira, 2009; Parreira et al., 2010). Our results corroborate these findings as reductions in some breathing pattern variables in women compared with men were observed in the youngest age range as well as in elderlies.

For all positions, our results consistently showed that women presented lower volumes compared with men. Statistically lower V_{cw} were observed in women for all age ranges in at least one position. This reduction, in general, occurred in reason of a lower V_{AB} observed in women compared with men. Previous studies (Vershakelen & Demedts, 1995; Parreira et al., 2010) have also reported lower tidal volume in women compared with men, however, the compartmental analysis was not presented. This is an important advantage of optoelectronic plethysmography that is a method capable to perform chest wall tri-compartmental analyses allowing a more specific evaluation of chest wall volume changes (Parreira et al., 2012).

Women presented statistically higher pulmonary rib cage contribution to tidal volume compared with men in at least one position for mostly age ranges, except between 40 to 59 years. However, we have to consider that a type 2 error for these age ranges might have occurred. Our results contribute to show the influence of sex on

chest wall motion. Similar to our results, Romei et al. (2010) and Binnazzi et al. (2006) previously have observed a more thoracic pattern in women during quiet breathing. Bellemare, Jeannerete, and Couture (2003) attributed this pattern to thoracic dimensions of the chest wall evaluated by x-rays. These authors observed lower radial dimension of the rib cage in relation to height and greater inclination of the ribs in women compared with men that could confer a mechanical advantage to the women rib cage muscles. These structural differences may also explain the statistically higher RR observed for elderly women in supine position compared to men. Seated position leads to greater thoracic contributions to tidal volume, while supine position leads to greater abdominal contributions to tidal volume. Physiologically, in supine position women will have their chest wall movement changed for a more abdominal pattern, while they usually present a more costal pattern. This position, thus, might cause a little discomfort due to a mechanical disadvantage making them increasing the RR. This pattern was only observed in women with 60 years and above because associated to mechanical disadvantages, elderly women could also present reduction in rib cage compliance caused by the calcification of costal cartilage and costovertebral joints with aging (Chan & Welsh, 1988).

A limitation of this study is that we did not achieve the sample size calculation, therefore, we have to consider the chance of type 2 error for some outcomes. In addition, the lower number of participants at higher age ranges did not allow the development of reference values for age ranges from 60 to 69 years, 70 to 79 years, and eighty and above years separately, in reason of the discrepancy between the number of women and men for these age ranges. However, we have to consider that this difference might reflect the population distribution that is made up of a smaller number of older men compared do the number of old women.

CONCLUSION

In conclusion, reference values for breathing pattern using optoelectronic plethysmography during quiet breathing for each position: seated, supine with 45° of trunk inclination and supine were established through a multicentre study. In addition, the effect of sex was also evaluated, contributing to show that women present more thoracic pattern compared with men.

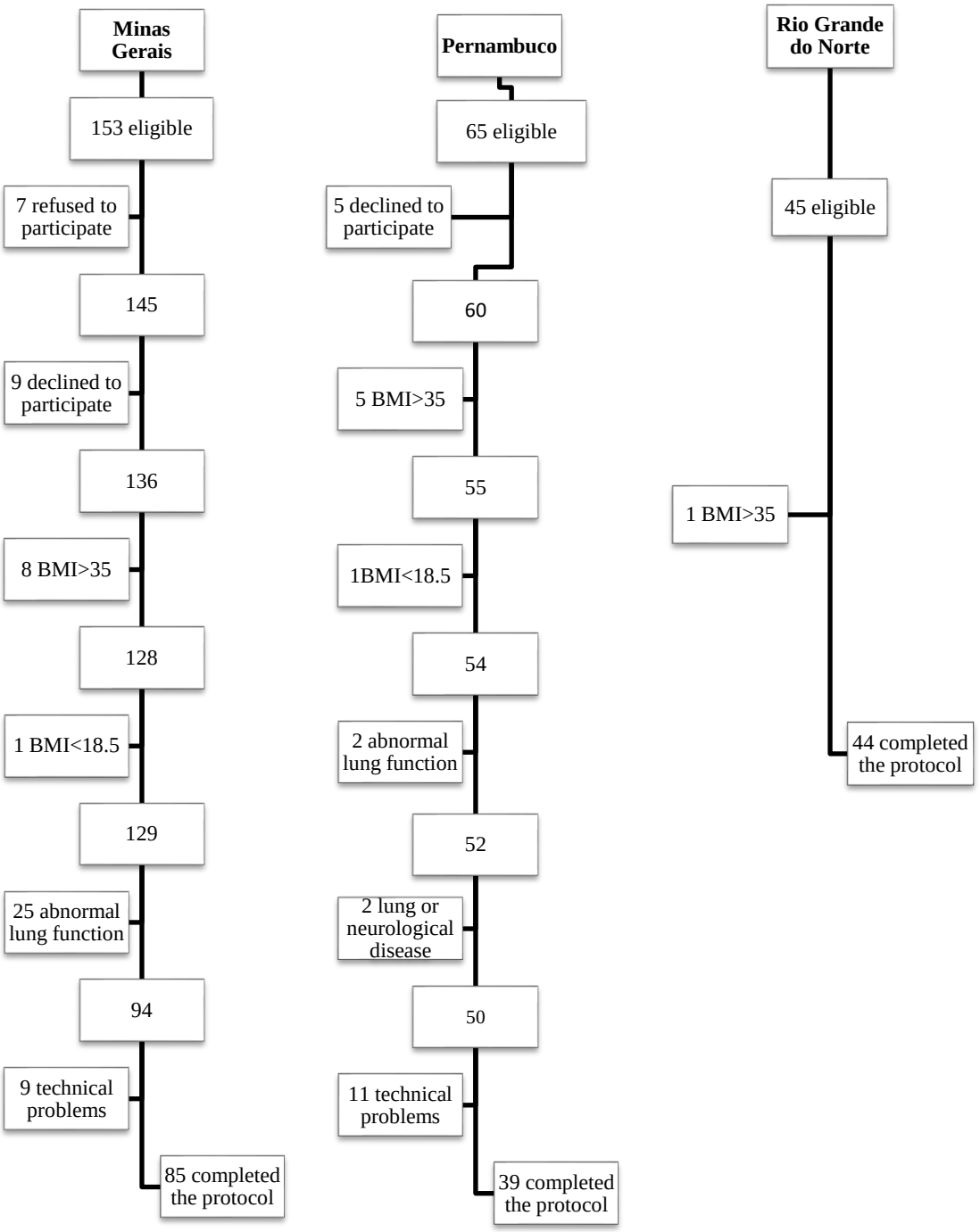


Figure 1. Flow of participants through the study in the three centers.

Table 1. Demographic, anthrophometric, spirometric, and clinical data of participants by sex (n=168).

Characteristic	All (n=168)	Men (n=61)	Women (n=107)	p value
Age (years)	52 (21)	42 (18)	52 (21)	< 0.0001*
	[21 - 91]	[21 - 81]	[21 - 91]	
BMI (Kg/m^2)	24.88 (3.22)	25.32 (2.68)	24.88 (3.22)	0.347
FEV_1 (% predicted)	94.45 (10.47)	94.05 (10.22)	94.45 (10.47)	0.813
FVC (% predicted)	93.82 (14.06)	94.22 (9.67)	93.81 (14.06)	0.157
FEV_1/FVC	0.82 (0.06)	0.83 (0.06)	0.83 (0.06)	0.993
HAP score	79.29 (14.00)	89.71 (7.22)	79.29 (14.00)	< 0.0001*
Inactive		0%	7%	
Mildly active		3%	23%	
Active		97%	70%	
MMSE		28 (2)	28 (2)	0.204

Values are expressed as mean (standard deviation. Minimal and maximal values for age are shown in brackets. BMI: body mass index; FEV_1: forced expiratory volume in first second; FVC: forced vital capacity; FEV_1/FVC: ratio of FEV_1 to FVC; HAP: Human Activity Profile; MMSE: Mini-Mental State Examination; *significant difference between sexes.

Table 2. Breathing pattern variables during quiet breathing in seated position by each age category.

	20 to 29 years		30 to 39 years		40 to 49 years		50 to 59 years		Sixty and above	
	Men (n=19)	**Women (n=17)**	**Men (n=16)**	**Women (n=16)**	**Men (n=6)**	**Women (n=17)**	**Men (n=6)**	**Women (n=11)**	**Men (n=14)**	**Women (n=46)**
V_{cw} (L)	0.81	0.53*	0.72	0.45*	0.70	0.59	0.50	0.44	0.71	0.52*
	(0.54 to 1.08)	(0.47 to 0.60)	(0.59 to 0.86)	(0.39 to 0.51)	(0.39 to 1.01)	(0.40 to 0.78)	(0.35 to 0.64)	(0.26 to 0.62)	(0.53 to 0.90)	(0.44 to 0.61)
V_{RCp} (L)	0.34	0.26	0.31	0.21*	0.27	0.24	0.18	0.19	0.20	0.21
	(0.22 to 0.45)	(0.20 to 0.31)	(0.24 to 0.38)	(0.16 to 0.25)	(0.11 to 0.45)	(0.18 to 0.30)	(0.12 to 0.24)	(0.09 to 0.30)	(0.14 to 0.26)	(0.17 to 0.25)
V_{RCa} (L)	0.19	0.11*	0.16	0.10*	0.13	0.13	0.11	0.09	0.12	0.10
	(0.13 to 0.25)	(0.09 to 0.12)	(0.11 to 0.21)	(0.07 to 0.12)	(0.05 to 0.20)	(0.08 to 0.17)	(0.06 to 0.16)	(0.05 to 0.12)	(0.08 to 0.16)	(0.09 to 0.12)
V_{AB} (L)	0.31	0.17*	0.25	0.15*	0.30	0.23	0.21	0.16	0.38	0.21*
	(0.22 to 0.40)	(0.15 to 0.19)	(0.20 to 0.19)	(0.12 to 0.18)	(0.16 to 0.44)	(0.12 to 0.33)	(0.08 to 0.19)	(0.09 to 0.33)	(0.26 to 0.50)	(0.16 to 0.26)
V_{rcp}%	39	46*	43	45	37	42	37	42	28	39*
	(36 to 42)	(41 to 52)	(38 to 48)	(38 to 51)	(27 to 46)	(36 to 48)	(22 to 52)	(34 to 49)	(22 to 35)	(36 to 43)
V_{rca}%	23	20*	22	21	18	21	21	20	18	21
	(21 to 25)	(18 to 22)	(18 to 25)	(17 to 25)	(12 to 25)	(17 to 24)	(14 to 29)	(13 to 27)	(13 to 21)	(18 to 24)
V_{ab}%	38	34	36	35	45	37	42	38	56	39*
	(35 to 41)	(28 to 40)	(31 to 41)	(28 to 41)	(34 to 56)	(32 to 43)	(23 to 60)	(28 to 48)	(46 to 63)	(35 to 44)
RR (bpm)	16	17	16	19	14	16	15	17	14	17
	(13 to 19)	(15 to 19)	(13 to 18)	(15 to 22)	(10 to 18)	(14 to 18)	(12 to 18)	(12 to 21)	(12 to 17)	(15 to 19)
VE (L/min)	11.98	8.67*	10.22	7.85*	9.29	8.40	7.01	6.33	9.08	7.56*
	(9.37 to 14.58)	(7.96 to 9.38)	(8.30 to 12.13)	(6.77 to 8.94)	(7.29 to 11.28)	(6.63 to10.17)	(5.51 to 8.51)	(5.40 to 7.26)	(8.19 to 9.97)	(6.86 to 8.27)
Ti (s)	1.69	1.51	1.90	1.40*	1.78	1.65	1.66	1.70	1.81	1.65
	(1.38 to 1.99)	(1.27 to 1.74)	(1.55 to 2.25)	(1.17 to 1.63)	(1.19 to 2.36)	(1.38 to 1.91)	(1.26 to 2.06)	(1.13 to 2.27)	(1.47 to 2.16)	(1.42 to 1.87)
Te (s)	2.34	2.27	2.60	2.20	2.80	2.55	2.60	2.44	2.91	2.59
	(2.07 to 2.61)	(2.00 to 2.54)	(2.05 to 3.15)	(1.89 to 2.51)	(2.09 to 3.52)	(2.16 to 2.95)	(1.76 to 3.45)	(1.52 to 3.35)	(2.06 to 3.76)	(2.13 to 3.04)
Ttot (s)	4.03	3.77	4.49	3.60	4.58	4.20	4.26	4.12	4.72	4.23
	(3.51 to 4.56)	(3.30 to 4.25)	(3.64 to 5.35)	(3.08 to 4.11)	(3.30 to 5.85)	(3.63 to 4.77)	(3.21 to 5.32)	(2.64 to 5.61)	(3.60 to 5.84)	(3.63 to 4.84)
Ti/TTot (%)	41	40	43	39*	40	40	40	41	40	40
	(39 to 44)	(37 to 42)	(40 to 46)	(37 to 41)	(35 to 43)	(37 to 42)	(34 to 46)	(40 to 43)	(36 to 44)	(38 to 42)

Values expressed as means and 95% Confidence Interval in brackets V_{cw}-chest wall tidal volume, V_{RCp}-pulmonary rib cage tidal volume, V_{RCa}-abdominal rib cage tidal volume, V_{AB}-abdomen tidal volume, $V_{RCp\%}$-pulmonary rib cage percentage contribution, $V_{RCa\%}$-abdominal rib cage percentage contribution, $V_{AB\%}$-abdomen percentage contribution, RR-respiratory rate, VE-minute ventilation; Ti-inspiratory time, Te-expiratory time, Ttot-total time of respiratory cycle, Ti/Ttot-duty cycle; *significant difference between sexes.

Table 2. (Continue**)** Breathing pattern variables during quiet breathing in seated position by each age category.

	20 to 29 years		30 to 39 years		40 to 49 years		50 to 59 years		Sixty and above	
	Men (n=19)	**Women (n=17)**	**Men (n=16)**	**Women (n=16)**	**Men (n=6)**	**Women (n=17)**	**Men (n=6)**	**Women (n=11)**	**Men (n=14)**	**Women (n=46)**
Vei_{cw} (L)	25	18*	27	19*	27	22*	22	21	25	24
	(24 to 26)	(17 to 19)	(25 to 30)	(17 to 20)	(22 to 32)	(20 to 23)	(16 to 28)	(18 to 24)	(22 to 28)	(22 to 25)
Vei_{RCp} (L)	14	11*	15	11*	15	13*	13	13	13	13
	(13 to 14)	(10 to 11)	(14 to 17)	(10 to 12)	(12 to 18)	(12 to 14)	(10 to 15)	(11 to 15)	(12 to 15)	(12 to 13)
Vei_{RCa} (L)	4.35	2.35*	4.36	2.63*	3.95	3.13	3.44	2.62	4.06	3.41*
	(3.90 to 4.80)	(2.14 to 2.56)	(3.62 to 5.09)	(2.26 to 3.00)	(2.41 to 5.48)	(2.75 to 3.50)	(1.56 to 5.31)	(2.00 to 3.24)	(3.53 to 4.59)	(3.12 to 3.72)
Vei_{AB} (L)	7.06	4.97*	7.59	5.05*	8.22	5.77*	6.31	5.51	7.98	7.48
	(6.44 to 7.69)	(4.56 to 5.37)	(6.51 to 8.66)	(4.25 to 5.86)	(6.17 to 10.27)	(5.24 to 6.30)	(3.51 to 9.11)	(4.69 to 6.32)	(6.60 to 9.36)	(6.86 to 8.10)
Vee_{cw} (L)	24	17*	27	18*	27	21*	22	20	24	23
	(23 to 25)	(16 to 18)	(24 to 29)	(17 to 20)	(21 to 32)	(20 to 23)	(16 to 28)	(18 to 423)	(21 to 28)	(22 to 24)
Vee_{RCp} (L)	13	10*	15	11*	15	12*	12	13	13	13
	(12 to 14)	(10 to 11)	(14 to 16)	(10 to 12)	(12 to 18)	(11 to 14)	(10 to 15)	(10 to 15)	(11 to 14)	(12 to 13)
Vee_{RCa} (L)	4.16	2.24*	4.20	2.52*	3.82	3.00	3.33	2.53	3.94	3.31*
	(3.72 to 4.60)	(2.04 to 2.45)	(3.48 to 4.91)	(2.16 to 2.88)	(2.34 to 5.31)	(2.67 to 3.35)	(1.51 to 5.16)	(1.94 to 3.13)	(3.41 to 4.46)	(3.01 to 3.61)
Vee_{AB} (L)	6.76	4.80*	7.33	4.90*	7.92	5.55*	6.10	5.34	7.60	7.27
	(6.14 to 7.37)	(4.40 to 5.19)	(4.40 to 5.19)	(6.27 to 8.40)	(4.40 to 5.19)	(5.87 to 9.97)	(3.37 to 8.82)	(4.57 to 6.12)	(6.24 to 8.96)	(6.65 to 7.89)
V_{cw}/Ti (L/s)	0.48	0.37*	0.41	0.35	0.40	0.35	0.30	0.26	0.39	0.33*
	(0.39 to 0.58)	(0.34 to 0.41)	(0.34 to 0.47)	(0.29 to 0.40)	(0.33 to 0.47)	(0.30 to 0.42)	(0.21 to 0.39)	(0.22 to 0.30)	(0.35 to 0.43)	(0.30 to 0.35)
V_{cw}/Te (L/s)	0.36	0.24*	0.31	0.22*	0.27	0.24	0.20	0.18	0.26	0.22*
	(0.27 to 0.44)	(0.22 to 0.27)	(0.24 to 0.38)	(0.19 to 0.25)	(0.19 to 0.35)	(0.18 to 0.30)	(0.16 to 0.23)	(0.16 to 0.21)	(0.23 to 0.30)	(0.20 to 0.24)

Values expressed as means and 95% Confidence Interval in brackets Vei_{cw}-end-inspiratory chest wall volume, Vei_{RCp}-end-inspiratory pulmonary rib cage, Vei_{RCa}-end-inspiratory abdominal rib cage volume, Vei_{AB}-end-inspiratory abdomen volume, Vee_{cw}-end-expiratory chest wall volume, Vee_{RCp}-end-expiratory pulmonary rib cage volume, Vee_{RCa}-end-expiratory abdominal rib cage volume Vee_{AB}-end-expiratory abdomen volume, V_{cw}/Ti-mean inspiratory flow, V_{cw}/Te-mean expiratory flow, *significant difference between sexes.

Table 3. Breathing pattern variables during quiet breathing in 45° of trunk inclination position by each age category.

	20 to 29 years		30 to 39 years		40 to 49 years		50 to 59 years		Sixty and above	
	Men (n=19)	**Women (n=17)**	**Men (n=16)**	**Women (n=16)**	**Men (n=6)**	**Women (n=17)**	**Men (n=6)**	**Women (n=11)**	**Men (n=14)**	**Women (n=46)**
V_{cw} (L)	0.60	0.43*	0.54	0.41*	0.45	0.44	0.43	0.37	0.57	0.48
	(0.45 to 0.75)	(0.38 to 0.48)	(0.43 to 0.65)	(0.35 to 0.47)	(0.34 to 0.56)	(0.38 to 0.50)	(0.34 to 0.52)	(0.28 to 0.47)	(0.48 to 0.66)	(0.41 to 0.55)
V_{RCp} (L)	0.22	0.20	0.17	0.16	0.11	0.16	0.13	0.15	0.14	0.17
	(0.14 to 0.29)	(0.17 to 0.23)	(0.12 to 0.21)	(0.12 to 0.19)	(0.04 to 0.18)	(0.12 to 0.20)	(0.11 to 0.16)	(0.10 to 0.19)	(0.11 to 0.16)	(0.13 to 0.21)
V_{RCa} (L)	0.09	0.06*	0.08	0.08	0.05	0.06	0.06	0.04	0.06	0.06
	(0.07 to 0.12)	(0.05 to 0.07)	(0.04 to 0.06)	(0.05 to 0.10)	(0.02 to 0.08)	(0.04 to 0.08)	(0.04 to 0.07)	(0.03 to 0.05)	(0.04 to 0.08)	(0.05 to 0.07)
V_{AB} (L)	0.29	0.17*	0.30	0.19*	0.29	0.22	0.24	0.19	0.37	0.25*
	(0.23 to 0.35)	(0.14 to 0.20)	(0.23 to 0.37)	(0.15 to 0.23)	(0.22 to 0.36)	(0.17 to 0.28)	(0.15 to 0.33)	(0.13 to 0.24)	(0.28 to 0.45)	(0.21 to 0.28)
V_{rcp}%	34	44*	31	39*	24	36	32	38	25	34*
	(29 to 39)	(37 to 51)	(24 to 37)	(34 to 43)	(15 to 34)	(29 to 43)	(22 to 42)	(31 to 45)	(20 to 30)	(30 to 39)
V_{rca}%	15	14	14	15	10	14	13	11	11	13
	(14 to 17)	(13 to 15)	(12 to 16)	(12 to 18)	(3 to 17)	(11 to 16)	(10 to 16)	(7 to 14)	(9 to 14)	(11 to 14)
V_{ab}%	51	39*	56	47	65	50*	55	51	64	53*
	(46 to 56)	(34 to 44)	(49 to 63)	(40 to 54)	(51 to 80)	(42 to 58)	(44 to 65)	(41 to 61)	(57 to 70)	(48 to 58)
RR (bpm)	16	16	16	17	17	16	15	17	15	16
	(13 to 18)	(14 to 17)	(13 to 18)	(14 to 20)	(13 to 21)	(14 to 19)	(13 to 18)	(14 to 20)	(12 to 117)	(14 to 19)
VE (L/min)	8.23	6.44*	7.73	6.40*	7.34	6.64	6.50	5.98	7.77	6.90
	(6.79 to 9.68)	(5.54 to 7.35)	(6.65 to 8.82)	(5.60 to 7.19)	(5.89 to 8.78)	(5.90 to 7.37)	(5.22 to 7.78)	(5.08 to 6.87)	(6.90 to 8.64)	(6.43 to 7.36)
Ti (s)	1.77	1.62	1.73	1.60	1.57	1.66	1.65	1.50	1.83	1.58
	(1.49 to 2.04)	(1.40 to 1.83)	(1.43 to 2.03)	(1.27 to 1.93)	(1.28 to 1.85)	(1.39 to 1.92)	(1.36 to 1.95)	(1.26 to 1.76)	(1.49 to 2.16)	(1.40 to 1.76)
Te (s)	2.57	2.52	2.63	2.39	2.18	2.50	2.36	2.34	2.80	2.82
	(2.13 to 3.01)	(2.14 to 2.90)	(2.11 to 3.15)	(1.90 to 2.88)	(1.69 to 2.66)	(2.15 to 2.85)	(1.95 to 2.77)	(1.75 to 2.92)	(2.03 to 3.57)	(2.29 to 3.36)
Ttot (s)	4.34	4.14	4.36	3.99	3.74	4.16	4.01	3.85	4.63	4.34
	(3.67 to 5.00)	(3.56 to 4.71)	(3.57 to 5.16)	(3.18 to 4.80)	(3.00 to 4.49)	(3.57 to 4.76)	(3.34 to 4.69)	(3.07 to 4.62)	(3.55 to 5.70)	(3.63 to 5.05)
Ti/TTot (%)	41	40	40	40	42	40	42	41	41	38
	(38 to 43)	(38 to 41)	(39 to 42)	(39 to 42)	(40 to 44)	(38 to 42)	(39 to 44)	(37 to 44)	(38 to 44)	(36 to 39)

Values expressed as means and 95% Confidence Interval in brackets V_{cw}-chest wall tidal volume, V_{RCp}-pulmonary rib cage tidal volume, V_{RCa}-abdominal rib cage tidal volume, V_{AB}-abdomen tidal volume, $V_{RCp\%}$-pulmonary rib cage percentage contribution, $V_{RCa\%}$-abdominal rib cage percentage contribution, $V_{AB\%}$.abdomen percentage contribution, RR-respiratory rate, VE-minute ventilation; Ti-inspiratory time, Te-expiratory time, Ttot-total time of respiratory cycle, Ti/Ttot-duty cycle; *significant difference between sexes.

Table 3. (Continue**)** Breathing pattern variables during quiet breathing in 45° of trunk inclination position by each age category.

	20 to 29 years		30 to 39 years		40 to 49 years		50 to 59 years		Sixty and above	
	Men (n=19)	**Women (n=17)**	**Men (n=16)**	**Women (n=16)**	**Men (n=6)**	**Women (n=17)**	**Men (n=6)**	**Women (n=11)**	**Men (n=14)**	**Women (n=46)**
Vei_{cw} (L)	20	16*	22	18	20	19	19	18	24	21
	(18 to 21)	(15 to 17)	(17 to 26)	(15 to 19)	(15 to 26)	(17 to 21)	(16 to 23)	(16 to 19)	(21 to 26)	(20 to 23)
Vei_{RCp} (L)	12	11	12	10	10	11	10	10	13	11*
	(10 to 13)	(10 to 11)	(10 to 14)	(9 to 12)	(7 to 14)	(10 to 13)	(8 to 13)	(8 to 12)	(11 to 15)	(10 to 12)
Vei_{RCa} (L)	2.91	1.38*	3.08	1.99*	2.65	2.29	2.52	1.96	2.98	2.71
	(2.44 to 3.39)	(1.16 to 1.60)	(2.61 to 3.55)	(1.61 to 2.36)	(1.48 to 3.81)	(1.77 to 2.82)	(1.30 to 3.74)	(1.49 to 2.43)	(2.60 to 3.37)	(2.28 to 3.14)
Vei_{AB} (L)	5.53	3.47*	7.62	5.07*	7.60	5.47	6.42	5.30	7.51	7.71
	(4.62 to 6.44)	(2.82 to 4.12)	(6.16 to 9.08)	(3.98 to 6.16)	(4.87 to 10.32)	(4.42 to 6.52)	(4.04 to 8.80)	(4.58 to 6.02)	(6.31 to 8.70)	(6.78 to 8.65)
Vee_{cw} (L)	19	15*	22	17*	20	19	19	17	22	21
	(18 to 21)	(14 to 16)	(19 to 26)	(15 to 19)	(14 to 26)	(16 to 21)	(15 to 22)	(16 to 19)	(20 to 26)	(19 to 22)
Vee_{RCp} (L)	11	11	12	10	10	11	10	10	13	11*
	(10 to 12)	(10 to 11)	(10 to 14)	(9 to 12)	(7 to 14)	(10 to 12)	(7 to 13)	(8 to 12)	(11 to 15)	(10 to 12)
Vee_{RCa} (L)	3.08	1.32*	3.00	1.93*	2.60	2.23	2.47	1.92	2.92	2.65
	(2.29 to 3.88)	(1.10 to 1.54)	(2.54 to 3.46)	(1.56 to 2.29)	(1.46 to 3.74)	(1.71 to 2.76)	(1.26 to 3.67)	(1.44 to 2.40)	(2.55 to 3.29)	(2.22 to 3.08)
Vee_{AB} (L)	5.25	3.30*	7.32	4.88*	7.31	5.25	6.18	5.11	7.14	7.46
	(4.35 to 6.15)	(2.66 to 3.94)	(5.89 to 3.94)	(3.82 to 8.75)	(4.63 to 9.98)	(4.23 to 6.26)	(3.84 to 8.52)	(4.42 to 5.81)	(5.96 to 8.33)	(6.54 to 8.38)
V_{cw}/Ti (L/s)	0.34	0.28	0.33	0.27	0.29	0.28*	0.27	0.25	0.32	0.32
	(0.29 to 0.39)	(0.23 to 0.32)	(0.28 to 0.37)	(0.23 to 0.30)	(0.24 to 0.34)	(0.25 to 0.32)	(0.21 to 0.32)	(0.20 to 0.30)	(0.28 to 0.36)	(0.29 to 0.34)
V_{cw}/Te (L/s)	0.24	0.18*	0.22	0.18*	0.21	0.19	0.19	0.17	0.23	0.19*
	(0.19 to 0.29)	(0.16 to 0.20)	(0.19 to 0.26)	(0.16 to 0.20)	(0.16 to 0.26)	(0.17 to 0.20)	(0.15 to 0.21)	(0.15 to 0.20)	(0.20 to 0.25)	(0.18 to 0.21)

Values expressed as means and 95% Confidence Interval in brackets Vei_{cw}-end-inspiratory chest wall volume, Vei_{RCp}-end-inspiratory pulmonary rib cage, Vei_{RCa}-end-inspiratory abdominal rib cage volume, Vei_{AB}-end-inspiratory abdomen volume, Vee_{cw}-end-expiratory chest wall volume, Vee_{RCp}-end-expiratory pulmonary rib cage volume, Vee_{RCa}-end-expiratory abdominal rib cage volume Vee_{AB}-end-expiratory abdomen volume, V_{cw}/Ti-mean inspiratory flow, V_{cw}/Te-mean expiratory flow, *significant difference between sexes.

Table 4. Breathing pattern variables during quiet breathing in supine position by each age category.

	20 to 29 years		30 to 39 years		40 to 49 years		50 to 59 years		Sixty and above	
	Men (n=19)	**Women (n=17)**	**Men (n=16)**	**Women (n=16)**	**Men (n=6)**	**Women (n=17)**	**Men (n=6)**	**Women (n=11)**	**Men (n=14)**	**Women (n=46)**
V_{cw} (L)	0.57	0.38*	0.53	0.29*	0.43	0.39	0.47	0.28*	0.51	0.41
	(0.41 to 0.73)	(0.34 to 0.42)	(0.44 to 0.62)	(0.18 to 0.40)	(0.31 to 0.56)	(0.29 to 0.50)	(0.28 to 0.66)	(0.21 to 0.35)	(0.31 to 0.72)	(0.35 to 0.46)
V_{RCp} (L)	0.14	0.10	0.14	0.07*	0.07	0.07	0.13	0.06	0.07	0.08
	(0.06 to 0.21)	(0.08 to 0.12)	(0.09 to 0.20)	(0.04 to 0.10)	(0.03 to 0.11)	(0.05 to 0.10)	(0.03 to 0.24)	(0.04 to 0.08)	(0.03 to 0.11)	(0.06 to 0.10)
V_{RCa} (L)	0.08	0.05*	0.07	0.04	0.04	0.05	0.06	0.04	0.04	0.04
	(0.05 to 0.11)	(0.04 to 0.06)	(0.04 to 0.09)	(0.02 to 0.06)	(0.04 to 0.06)	(0.01 to 0.06)	(0.01 to 0.11)	(0.02 to 0.07)	(0.02 to 0.07)	(0.03 to 0.05)
V_{AB} (L)	0.35	0.23*	0.32	0.18*	0.33	0.28	0.28	0.19	0.40	0.29
	(0.28 to 0.43)	(0.19 to 0.27)	(0.27 to 0.36)	(0.10 to 0.25)	(0.23 to 0.42)	(0.19 to 0.37)	(0.19 to 0.37)	(0.13 to 0.24)	(0.22 to 0.57)	(0.25 to 0.32)
V_{rcp}%	21	28	25	18	16	18	27	18	12	18
	(16 to 26)	(23 to 33)	(19 to 32)	(11 to 25)	(7 to 24)	(11 to 24)	(14 to 40)	(12 to 25)	(6 to 17)	(14 to 22)
V_{rca}%	13	13	12	11	9	11	13	13	6	10
	(11 to 15)	(12 to 14)	(9 to 14)	(7 to 15)	(3 to 14)	(8 to 15)	(7 to 19)	(7 to 19)	(3 to 9)	(8 to 11)
V_{ab}%	66	59	63	46	76	60	60	60	61	68
	(60 to 72)	(54 to 64)	(55 to 71)	(31 to 62)	(63 to 88)	(47 to 73)	(43 to 77)	(45 to 74)	(41 to 80)	(62 to 74)
RR (bpm)	17	17	16	14	16	13	15	17	10	16*
	(15 to 19)	(14 to 19)	(13 to 18)	(8 to 19)	(13 to 20)	(10 to 17)	(14 to 16)	(12 to 21)	(7 to 14)	(14 to 18)
VE (L/min)	8.50	6.04*	7.60	6.15	6.75	6.04	6.62	5.48	7.67	6.31*
	(7.00 to 10.00)	(5.36 to 6.73)	(6.46 to 8.73)	(5.28 to 7.02)	(5.53 to 7.97)	(5.30 to 6.78)	(4.76 to 8.49)	(4.78 to 6.18)	(7.04 to 8.30)	(5.84 to 6.77)
Ti (s)	1.71	1.60	1.74	1.58	1.64	1.73	1.83	1.42*	1.90	1.55
	(1.43 to 1.99)	(1.37 to 1.84)	(1.55 to 1.92)	(1.14 to 2.00)	(1.34 to 1.94)	(1.43 to 2.03)	(1.49 to 2.16)	(1.22 to 1.62)	(1.45 to 2.34)	(1.41 to 1.70)
Te (s)	2.24	2.43	2.65	1.82	2.21	2.53	2.37	1.85	2.79	2.68
	(1.93 to 2.54)	(1.93 to 2.93)	(2.11 to 3.19)	(0.99 to 2.65)	(1.77 to 2.64)	(1.84 to 3.23)	(2.12 to 2.61)	(1.32 to 2.38)	(1.60 to 3.98)	(2.20 to 3.16)
Ttot (s)	3.95	4.03	4.38	3.00	3.84	4.06	4.19	3.14	4.28	4.16
	(3.39 to 4.51)	(3.30 to 4.76)	(3.71 to 5.06)	(1.69 to 4.31)	(3.12 to 4.57)	(3.02 to 5.11)	(3.69 to 4.69)	(2.31 to 3.97)	(2.58 to 5.98)	(3.54 to 4.79)
Ti/TTot (%)	43	44	42	40	35	38	43	42	38	38
	(41 to 45)	(37 to 51)	(39 to 44)	(38 to 42)	(17 to 54)	(35 to 41)	(40 to 48)	(38 to 46)	(34 to 42)	(37 to 40)

Values expressed as means and 95% Confidence Interval in brackets V_{cw}-chest wall tidal volume, V_{RCp}-pulmonary rib cage tidal volume, V_{RCa}-abdominal rib cage tidal volume, V_{AB}-abdomen tidal volume, $V_{RCp\%}$-pulmonary rib cage percentage contribution, $V_{RCa\%}$-abdominal rib cage percentage contribution, $V_{AB\%}$-abdomen percentage contribution, RR-respiratory rate, VE-minute ventilation; Ti-inspiratory time, Te-expiratory time, Ttot-total time of respiratory cycle, Ti/Ttot-duty cycle; *significant difference between sexes.

Table 4. (Continue**)** Breathing pattern variables during quiet breathing in supine position by each age category.

	20 to 29 years		30 to 39 years		40 to 49 years		50 to 59 years		Sixty and above	
	Men (n=19)	**Women (n=17)**	**Men (n=16)**	**Women (n=16)**	**Men (n=6)**	**Women (n=17)**	**Men (n=6)**	**Women (n=11)**	**Men (n=14)**	**Women (n=46)**
Vei_{cw} (L)	21	17*	24	13*	23	18	20	17	20	22
	(19 to 23)	(16 to 19)	(21 to 28)	(8 to 17)	(16 to 29)	(14 to 22)	(17 to 24)	(13 to 22)	(13 to 26)	(20 to 24)
Vei_{RCp} (L)	9	9	12	8*	10	10	9	9	11	9*
	(8 to 10)	(8 to 9)	(10 to 14)	(7 to 9)	(6 to 14)	(9 to 11)	(8 to 10)	(8 to 10)	(10 to 13)	(8 to 10)
Vei_{RCa} (L)	3.95	2.54*	3.72	2.12*	3.50	3.21	3.46	3.33	2.88	4.40*
	(2.25 to 2.83)	(2.25 to 2.83)	(3.26 to 4.19)	(1.35 to 2.88)	(2.10 to 4.90)	(2.36 to 4.05)	(2.33 to 4.59)	(1.92 to 4.75)	(1.94 to 3.81)	(3.72 to 5.07)
Vei_{AB} (L)	7.87	6.30*	8.64	5.84*	8.89	7.04	7.97	6.44	9.94	9.26
	(7.06 to 8.68)	(5.80 to 6.79)	(7.25 to 10.04)	(4.70 to 6.99)	(6.06 to 11.71)	(6.16 to 7.93)	(5.70 to 10.23)	(5.60 to 7.28)	(8.29 to 11.59)	(8.44 to 10.08)
Vee_{cw} (L)	21	17*	24	13*	22	17	20	17	19	22
	(19 to 23)	(16 to 18)	(20 to 27)	(8 to 17)	(15 to 29)	(14 to 21)	(16 to 24)	(13 to 21)	(13 to 26)	(20 to 23)
Vee_{RCp} (L)	9	8	12	8*	10	9	9	9	11	9*
	(8 to 10)	(8 to 9)	(10 to 14)	(7 to 9)	(6 to 14)	(8 to 10)	(7 to 10)	(8 to 10)	(10 to 13)	(8 to 9)
Vee_{RCa} (L)	3.87	2.49*	3.66	2.07*	3.46	3.16	3.40	3.29	2.84	4.36*
	(3.44 to 4.30)	(2.21 to 2.78)	(3.20 to 4.11)	(1.33 to 2.82)	(2.07 to 4.85)	(2.33 to 4.00)	(2.29 to 4.51)	(1.90 to 4.69)	(1.92 to 3.76)	(3.68 to 5.03)
Vee_{AB} (L)	7.47	6.06*	8.33	5.61*	8.56	6.73	7.70	5.42	9.43	8.96
	(6.67 to 8.27)	(5.57 to 6.55)	(6.95 to 9.71)	(4.50 to 6.72)	(5.77 to 11.35)	(5.89 to 7.57)	(5.45 to 9.94)	(5.42 to 7.05)	(7.80 to 11.06)	(8.14 to 9.78)
V_{cw}/Ti (L/s)	0.33	0.25*	0.31	0.19*	0.27	0.24	0.26	0.20	0.27	0.27
	(0.27 to 0.39)	(0.22 to 0.28)	(0.27 to 0.36)	(0.13 to 0.26)	(0.21 to 0.32)	(0.18 to 0.29)	(0.19 to 0.33)	(0.15 to 0.26)	(0.18 to 0.37)	(0.24 to 0.30)
V_{cw}/Te (L/s)	0.25	0.17*	0.23	0.17*	0.20	0.17	0.20	0.16	0.22	0.18*
	(0.21 to 0.30)	(0.15 to 0.19)	(0.19 to 0.27)	(0.14 to 0.20)	(0.17 to 0.24)	(0.15 to 0.19)	(0.13 to 0.27)	(0.14 to 0.18)	(0.19 to 0.24)	(0.16 to 0.19)

Values expressed as means and 95% Confidence Interval in brackets Vei_{cw}-end-inspiratory chest wall volume, Vei_{RCp}-end-inspiratory pulmonary rib cage, Vei_{RCa}-end-inspiratory abdominal rib cage volume, Vei_{AB}-end-inspiratory abdomen volume, Vee_{cw}-end-expiratory chest wall volume, Vee_{RCp}-end-expiratory pulmonary rib cage volume, Vee_{RCa}-end-expiratory abdominal rib cage volume Vee_{AB}-end-expiratory abdomen volume, V_{cw}/Ti-mean inspiratory flow, V_{cw}/Te-mean expiratory flow, *significant difference between sexes.

CHAPTER 4

GLITTRE-ADL TEST WITH AND WITHOUT A BACKPACK IN PEOPLE WITH CHRONIC PULMONARY DISEASE

INTRODUCTION

The Glittre-ADL test (Skumlien et al., 2006) has been proposed as a test that is more reflective of functional activities than other functional exercise tests for people with chronic obstructive pulmonary disease (COPD) as it includes standing from a chair, walking, climbing stairs and a grocery shelving task. These activities were chosen to represent common tasks of everyday life (Skumlien et al., 2006; Correa et al., 2011; Bui et al., 2017).

In the Glittre-ADL test, patients wear a backpack filled with 2.5 kg for women or 5.0 kg for men. The weight of 2.5 kg simulates the weight of a supplementary oxygen equipment, which can be exchanged for the weight when appropriate. In order to standardize the test time for gender, the authors doubled the weight for men (Skumlien et al., 2006). However, further investigation on this method of correcting for gender differences has not been investigated (Dechman & Scherer, 2008). Recent studies (Oliveira et al., 2017; Castro et al., 2016) have reported deficits in balance and coordination in people with COPD, therefore, the backpack may contribute to limiting capacity during the test (Oliveira et al., 2017; Butcher et al., 2004). In addition, in clinical practice or in the community is not common for patients to carry oxygen in backpacks.

Due to the lack of studies regarding the increase in the backpack weight to standardize the test for gender and that the weighted backpack may adversely affect the

balance of the participants, this study aimed to assess the differences in performance of the Glittre-ADL test with and without the backpack in people with COPD.

The primary aim of this study was to compare the difference in test time, physiological responses and symptoms in performing the Glittre-ADL test with and without the backpack in people with COPD. The secondary aims were: i) to evaluate the relationship between the Glittre-ADL test performed without the backpack and the six-minute walk test (6MWT); ii) to investigate the change in Glittre-ADL test performed without the backpack when assessed before and after a pulmonary rehabilitation program.

METHODS

Participants and study design

This was a cross-sectional study. Participants were recruited from referrals to an outpatient pulmonary rehabilitation program at Royal Prince Alfred Hospital, Sydney, Australia and to an outpatient pulmonary rehabilitation program at Federal University of Minas Gerais, Belo Horizonte, Brazil. Participants were included in the study if they had a diagnosis of COPD stage I to IV disease severity (GOLD, 2019) and were stable over the past month. Exclusion criteria were: concomitant cardiovascular, orthopaedic or neurological conditions that were likely to impair exercise performance; other significant pulmonary disease; body mass index over 35kg/m^2; major psychiatric illness. Written informed consent was obtained from all participants. The trial was registered ANZCTR 12617000920392 and was approved by Ethics Committees from Australia (X14-0199 & HREC/14/RPAH/261) and Brazil (CAAE: 02288818.0.0000.5149).

Measures

Glittre-ADL test

The Glittre-ADL test has been described previously (Skumlien et al., 2006). In brief, participants stand up from a chair and then walk along a 10 metre track in which there are three steps to walk up and down. At the end of the track participants perform a shelving task of moving three weights of 1.0 kg each (one by one) from the top shelf to the bottom shelf and then down to the floor and then back to the bottom shelf and to the top shelf again. Participants then turn and walk back over the steps and sit down. This is one lap. Participants then immediately start the next lap (Figure 1). Technical details including dimensions of the stairs and adjustments of the shelf heights have been previously published (Skumlien et al., 2006). The primary outcome of the test is the time taken to complete five laps. Participants are allowed to stop and rest during the test, but they are instructed to resume the test as soon as possible. During the test, participants wear a backpack filled with 2.5 kg for women or 5.0 kg for men (Skumlien et al., 2006). In our study, the test performed without the backpack was identical to the Glittre-ADL test, except that participants did not wear a backpack.

Other measures

Spirometry was performed using calibrated portable spirometers (Easy One spirometer; nnd Medical Technologies Inc., Andover, MA, USA for Australian participants and Koko, Ferraris Respiratory, USA, for Brazilian participants) according to standard procedures (Miller et al., 2005). Obtained measures were compared to normative data (Gore et al., 1995; Pereira et al., 2007) and disease severity was classified according to GOLD criteria (GOLD, 2019).

Functional capacity was measured by the distance walked in the 6MWT (Butland et al., 1982; Cooper, 1968), which was performed according to previous published protocols (Holland et al., 2014).

Health-related quality of life (HRQoL) was measured by the St George's Respiratory Questionnaire (SGRQ) which has 53 items and assess three domains: symptoms, activity limitations and impact of disease (Jones et al., 1992).

Procedures

Participants attended for three data collection sessions over a 14-day period. On the first visit, demographic data such as height, weight and age were recorded. The participants then performed spirometry, completed the SGRQ, and completed two 6MWTs with the best distance recorded for analysis. On the second visit, participants performed two Glittre-ADL tests (test 1 and test 2) with the backpack to eliminate the learning effect. On the third visit, participants completed one Glittre-ADL test with the backpack and one without the backpack, in random order. The order of the tests was randomized in blocks by a computer program (https://www.random.org/). The randomisation sequence was kept in sealed, opaque envelopes and only opened prior to tests carried out on visit 3. After completing both tests, participants completed a questionnaire, which asked about the ease of performing each test, particularly control of balance and ability to perform the tasks. Participants rested for 30 minutes between each test or until all parameters had returned to baseline levels. The time to complete five laps of each Glittre-ADL test on the second and third days were recorded as the test outcomes. During all exercise tests, oxygen saturation (SpO_2) and pulse rate were continuously monitored (Masimo Rad 5, Masimo Corporation or Novametric, Respironics for Australian participants and Nonin 8000R, Nonin Medical Inc, USA, for Brazilian participants). Dyspnoea and rate of perceived exertion (RPE) were assessed

before and immediately at the end of each test using the modified 0-10 Scale (Borg 1982).

In a small sub-group, the responsiveness to pulmonary rehabilitation of the Glittre-ADL test performed without the backpack was tested. The participants attended an eight-week pulmonary rehabilitation program twice a week in which they performed 20 minutes of stationary cycling, 20 minutes of walking, 10 minutes of upper limb strength and endurance exercises and 10 minutes of lower limb strength and endurance exercises. The order of the assessments after pulmonary rehabilitation was randomized by the same computer program. The randomisation sequence was kept in sealed, opaque envelopes and only opened prior to tests at the end of the program.

Sample size

The sample size calculation was based on a pilot study and was calculated on equivalence between Glittre-ADL tests performed with and without the backpack. Equivalence of SpO_2 and heart rate, were chosen as the physiological variables of equivalence and the standard deviations (SD) of these measurements in the first ten participants of the study (3% for SpO_2, and 18 beats per minute for HR) were used in the calculation of sample size. A power of 0.90, an alpha of 5% and an equivalence limit of 3% for SpO_2 (Pierri, Escourrou, Delaperche & Visseaux, 1990), 14 beats per minute for heart rate (Jensen et al., 2013) were considered. The calculation determined a sample size of 22 participants for SpO_2 and 36 for heart rate.

Data analysis

Data are presented as mean and standard deviation, unless otherwise stated and the normality was verified by the Shapiro-Wilk test. The comparisons between genders for demographic, spirometric and clinical variables were performed by Student *t* test for independent samples, and Mann-Whitney or chi-square test, according to the

characteristic and/or variable distribution. Comparisons between Glittre-ADL test times with and without the backpack were performed by paired *t*-tests. To verify the relationship between the Glittre-ADL tests performed with and without the backpack and between the Glittre-ADL test time and the distance walked on 6MWT, the Pearson or Spearman correlation coefficient were used, according to data normality. The strength of the correlations was defined as < 0.20 as minimal or absent, from 0.25 to 0.50 as weak, from 0.50 to 0.75 as moderate, and from 0.75 to 1.0 as strong (Portney & Watkins, 2009). The level of significance was set at 5%. The Statistical Package for the Social Sciences (SPSS) v 15.0 (Chicago, IL, USA) was used for analyses.

RESULTS

Participant characteristics

The flow chart of study participants is presented in figure 1. Forty participants were recruited and completed the comparison of Glittre-ADL with and without the backpack, and twenty of these participants completed the comparison of the Glittre-ADL without the backpack before and after pulmonary rehabilitation. Table 1 presents demographic, anthropometric, spirometric, and clinical data of the participants. Three participants were classified as GOLD 1, 15 as GOLD 2, 14 as GOLD 3, and 8 as GOLD 4. Participants were divided in two sub-groups according to gender. The sub-groups were similar for most characteristics. Men had more severe disease and reported greater impact of the disease in HRQoL compared with women.

Differences in performing Glittre-ADL test with and without the backpack

Table 2 shows the results for Glittre-ADL tests performed with and without the backpack for the total group and for males and females. The time for the test was significantly shorter without the backpack for total group and males. The Glittre-ADL

test performed without the backpack provoked the same physiological responses and symptoms to the Glittre-ADL test with the backpack, except for upper limb fatigue that was reported by males as significantly higher for the test performed with the backpack. In addition, males scored significantly higher dyspnoea compared to females for the test performed with the backpack. 78% of the participants reported greater ease in performing the test without the backpack. Of these, 61% mentioned greater ease in standing up from the chair and bending down and bending over during the shelving task, 57% reported greater ease in walking up and down the steps, 51% reported greater ease in walking and 39% in controlling balance.

Relationship between Glittre-ADL tests and six-minute walk test

Correlations between Glittre-ADL tests and six-minute walk test are presented in table 3. Glittre-ADL Test time performed with the backpack was moderately correlated with the six-minute walk test distance for the total group (rho = -0.606; p= <0.001), and females (rho = -0.687; p= 0.001) while the correlation for males was weak (rho = -0.466; p= 0.033). On the other hand, the correlation for Glittre-ADL test performed without the backpack was moderate for total group (rho = -0.683; p= <0.001), males (rho = -0.699; p= <0.001), and females (rho = -0.676; p= <0.001).

Responsiveness of Glittre tests to pulmonary rehabilitation

Twenty participants completed the Glittre-ADL test with and without the backpack before and after pulmonary rehabilitation. Participant characteristics are presented in Table 4. Eleven participants were classified as GOLD 2, 5 as GOLD 3, and 4 as GOLD 4. After pulmonary rehabilitation there were significant improvements in the Glittre-ADL test time performed with and without the backpack and in the six-minute walk test distance (Table 5). The effect size of the Glittre-ADL test performed without the backpack was higher than the test performed with the backpack.

Repeatability

For the Glittre-ADL test with the back pack on the second visit (test 1 and test 2), there was significant decline in test time from test 1 to test 2 [4.84±1.98 min vs 4.47±1.95 min; mean difference 0.36 minute (95%CI 0.03 to 0.70; p= 0.036)] demonstrating that the second test was completed more quickly which indicates a learning effect of 9%. For the Glittre-ADL test performed with the back pack (on visit 3) there was no significant difference in test time compared to test 2 [mean difference 0.21 minute (95%CI -0.003 to 0.42; p= 0.053)], indicating no further learning effect. When test 1 and test 2 were compared, there was no significant difference in the final dyspnoea scores (4±1 vs 4±2 points, p=0.675), final heart rate (120±17 vs 119±16 beats per minute, p=0.568) and final SpO_2 (91±7 vs 91±7 %, p=0.675).

DISCUSSION

The findings of this study demonstrated that: 1) the time to perform the Glittre-ADL test without the backpack was significantly shorter than the Glittre-ADL test for total group and for males; 2) the test performed without the backpack provoked the same physiological response and symptoms as the Glittre-ADL test with the backpack, except for upper limb fatigue that was reported by males as significantly higher for the test performed with the backpack; 3) the Glittre-ADL test without the backpack was moderately correlated with the 6MWT distance; 4) the Glittre-ADL test performed without the backpack was responsive to change following a pulmonary rehabilitation program.

The Glittre-ADL test has been increasingly used to assess patients with COPD (Skumlien et al., 2006; Skumlien et al., 2008; Correa et al., 2011; Karloh et al., 2014; Tufanin et al., 2014; de Araujo et al, 2015; dos Santos et al, 2016; Calik-Kutukcu et al,

2015). The test has the advantage of assessing the function of both the arms and legs (Bui et al., 2017), has strong correlation with the 6MWT (Skumlien et al., 2006; Jose & Carso, 2013; Karloh et al., 2014) and shows good responsiveness to pulmonary rehabilitation (Skumlien et al., 2006). The total group and males performed the test without the backpack 9% faster, than with the backpack. In the test with the backpack, participants have to carry a backpack filled with 2.5 kg for women and 5.0 kg for men, thus it is expected that the performance of the test without the backpack would make more difference for men than women. According to the authors who proposed the test (Skumlien et al., 2006), the backpack simulates the weight of a supplementary oxygen equipment which can be exchanged for oxygen cylinder when appropriate. However, the weight of a supplementary oxygen equipment is the same for both sexes, thus the weight for men and women in the backpack should be the same. In addition, in real life usually patients do not have to carry the oxygen while performing tests as the cylinder can be put on a trolley.

The authors attributed the necessity to double the weight in the backpack for men to standardize the test time for genders (Skumlien et al., 2006). However, further investigation on this method of correcting for gender differences needs to be investigated (Dechman & Scherer, 2008). It is well known that sex influences the performance on functional tests such as the six-minute walk test (ATS, 2002), the incremental shuttle walk test and the endurance shuttle walk test (Holland et al., 2014). However, the differences are assumed and reference equations according to expected variations, including sex, have been created (Holland et al., 2014). Therefore, the necessity to standardize test time for genders doubling the weight for men to decrease the physiological advantage they have should be further studied. The only difference between sexes observed in this study was the higher dyspnoea reported by males

compared to females at the end of the test performed with the backpack, which may be due to the heavier backpack that they had to carry during the test.

In 2008, Dechman & Scherer (Dechman & Scherer, 2008) suggested that weight adjustments for sexes could affect test validity. A number of studies since then have evaluated adjustments to the use of a backpack in modified versions of the Glittre-ADL test. Santos et al (Santos et al., 2016) evaluated a modified shelf protocol (higher shelf) using 2.5kg in the backpack for both sexes. The authors justified that the change was made to reduce the overload caused by the backpack weight carried by men. Monteiro et al (Monteiro et al., 2017) later, in a modified version of Glittre-ADL test, used a backpack with 10% of post bariatric surgery patient's body weight. The same adjustment was made for obese individuals and healthy controls using 10% of their body weight in the backpack and all participants carried out each activity component of Glittre-ADL test for 2 minutes (Monteiro et al., 2017). More recently, Martins et al (Martins et al., 2017) also suggested using a backpack weight based on children's weight according to the child's age and gender. Our findings showed that the test without the backpack provoked the same physiological responses and symptoms as the test with the backpack, except for the higher fatigue of upper limbs reported by males for the test performed with the backpack. Previously, Cavalheri et al (Cavalheri et al., 2011) have observed similar physiological responses and symptoms for patients with COPD walking on the level for one minute with a weighted backpack (5 kg for men and 2.5 kg for women) and without a backpack. In addition, the energy expenditure measured by indirect calorimetry and pedometers were also the same for these activities (Cavalheri et al., 2011). Similar results were observed by Monteiro et al (Monteiro et al., 2017) evaluating the energy expenditure for post-bariatric surgery patients walking with and without a backpack for 2 minutes. Although only walking was evaluated in

these studies rather than including all the activities in the Glittre-ADL test, these findings are an indication that the backpack may not make much difference to test performance. Although in our study males reported higher fatigue of the upper limbs for the test performed with the backpack, the physiological response of SpO_2 and HR were the same, indicating that the backpack might cause more discomfort but that does not make a difference to these physiological measures. The upper limb fatigue was only observed for males who had to carry double the weight of females during the test. While there were slight gender differences due to the differences of the backpack weight in the Glittre-ADL test performed with the backpack, when the total group was considered, the test without the backpack provoked the same physiological responses and symptoms as the test performed with the backpack.

The validity of the Glittre-ADL test has been previously demonstrated by comparisons with the 6MWT which showed strong correlations between Glittre-ADL time and the 6MWT distance ($r=-0.82$, $p<0.001$) (Skumlien et al., 2006) and strong correlation between the oxygen uptake (VO_2) measured at the end of the Glittre-ADL test and the 6MWT ($r=0.87$, $p< 0.05$) (Karloh et al., 2014). In addition, Glittre-ADL test time showed moderate correlations with the London Chest Activity of Daily Living ($r=0.67$, $p<0.05$) (Correa et al., 2011); weak correlation with the activity domain of the St George's Respiratory Questionnaire ($r=0.43$, $p<0.001$) (Skumlien et al., 2006); and moderate correlations with time spent in the sitting position ($r=0.50$, $p<0.05$), number of steps taken ($r= -0.53$, $p<0.05$), walking movement intensity ($r= -0.66$, $p<0.05$), and walking energy expenditure ($r= -0.50$, $p<0.05$) measured by an activity monitor (Karloh et al., 2016). In our study, the Glittre-ADL test performed without the backpack and with the backpack showed a moderate correlation with the 6MWT distance ($r=-0.61$, $p< 0.001$ and $r=-0.68$, $p< 0.001$, respectively) (Portney & Walkins, 2009). The 6MWT was

chosen as the comparison test for the Glittre-ADL test because it is the most widely used test to assess functional capacity in people with COPD (Holland et al., 2014), and has similar constructs to the Glittre-ADL test in that both tests are self-paced and assess a similar construct of functional capacity after pulmonary rehabilitation, since the patients have to perform the tests faster to show improvements after pulmonary rehabilitation (Bui et al., 2017).

The Glittre-ADL test has been shown to be responsive to change after pulmonary rehabilitation (Skumlien et al., 2006; Gullart et al., 2018). Skumilen et al (Skumlien et al., 2006) demonstrated a mean difference of –0.89 minutes, 95% CI (-0.48 to 1.30) after 4 weeks of rehabilitation. In contrast, Calik-Kutukcu et al (Calik-Kutukcu et al., 2015) did not show improvement on the Glittre-ADL test in COPD patients after 23 supervised rehabilitation sessions, consisting only of arm strength training rather than a standard program. Our study demonstrated a mean difference of –0.52 minutes, 95% CI (-0.81 to -0.22) for the test performed with the backpack and a mean difference of –0.41 minutes, 95% CI (-0.63 to -0.18) for the test performed without the backpack after eight weeks of pulmonary rehabilitation. The effect sizes for both tests were large (d=0.82 and d=0.86 respectively) (Cohen, 1988), but lower than the effect size observed for the 6MWT (d=1.10). The greater effect size of the 6MWT can be explained by the fact that this assessment after pulmonary rehabilitation involved only one functional activity (walking) while Glittre-ADL test with the backpack involved at least ten activities (carrying on shoulders and back, sitting, standing, walking, stair climbing, reaching, lifting, putting down objects, grasping and releasing) making the 6MWT easier compared to the Glittre-ADL tests. Karloh et al (Karloh et al., 2014) showed that Glittre-ADL test induced a higher final VO_2 than 6MWT reinforcing that Glittre-ADL test required greater energy expenditure than the 6MWT. Recently,

Gullart et al (2018), in a study of 60 participants with COPD who completed 24 sessions of pulmonary rehabilitation, determined the minimal important difference for the Glittre-ADL test performed with the backpack, as a reduction of 0.38 minutes. Participants in our study achieved the minimal important difference for the Glittre-ADL test after 16 sessions of pulmonary rehabilitation. The minimal important difference for Glittre-ADL test performed without the backpack has not yet been determined, however, the time reduction observed in our study was superior to the proposed minimal important difference for the test performed with the backpack.

A learning effect for Glittre-ADL test is evident, with a test-retest reliability varying between 6-7% (dos Santos et al., 2016; Skumlien et al., 2006)) to 17% (Jose & Dal Corso, 2015) from the first to the second test. Our findings showed a learning effect of 9% for the first two tests performed with the backpack, with no further learning effect when the test was carried out for the third time.

Despite complexity, the Glittre-ADL test has been considered a most promising and comprehensive functional test for clinical practice as it includes eleven links to the International Classification of Functioning, Disability and Health as it assesses functional upper and lower limb exercise capacity through different activities which are important for mobility and participation in daily life (Bui et al., 2017).

A limitation of this study was that there was no direct measure of metabolic and ventilatory responses during the tests. Such measures could contribute to understanding the metabolic and ventilatory differences in performing the GlittreADL tests with and without the backpack. In addition, the study did not include participants using oxygen therapy, therefore it is not possible to generalise the findings to this group. The sample size was calculated to evaluate the equivalence of the physiological variables of SpO_2 and HR when the Glittre-ADL without the backpack was compared to with the

backpack, but not for symptoms of dyspnoea or perceived exertion. Despite this, only small differences, which were not statistically or clinically significant, were shown in dyspnoea or RPE Leg or RPE Arm when Glittre-ADL with and without the backpack were compared for the total group, further supporting the equivalence of the Glittre-ADL without backpack to that with the backpack.

CONCLUSION

In conclusion, the Glittre-ADL test performed without the backpack provoked the same physiological responses and symptoms as the test with the backpack, except for upper limb fatigue that was reported by males as significantly higher for the test performed with the backpack. The test without the backpack was reported by participants as more tolerable, thus, it is reasonable to suggest that the Glittre-ADL test without the backpack may be a safer test, especially for patients with problems of balance and coordination, while still remaining a good test of functional capacity for activities of daily living.

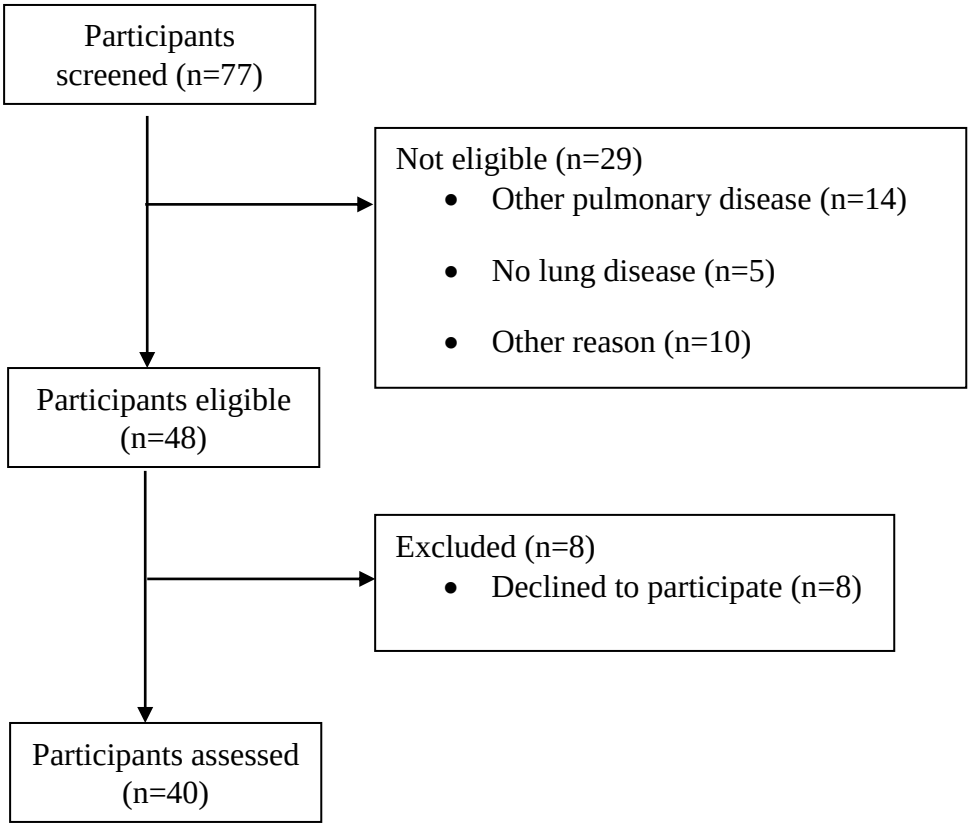


Figure 1. Flow of participants through the study.

Table 1. Characteristics of study participants (n=40).

Characteristic	All Mean (SD) n=40	Male Mean (SD) n=21	Female Mean (SD) n=19	Male vs Female p value
Age, years	70 (6)	70 (7)	70 (6)	0.731
BMI, Kg/m^2	23 (5)	24 (4)	22 (5)	0.132
FEV$_1$, % pred	48 (20)	42 (18)	54 (20)	0.046*
FVC, % pred	83 (27)	74 (23)	92 (28)	0.034*
FEV$_1$/FVC	0.46 (0.13)	0.46 (0.14)	0.47 (0.11)	0.559
SGRQ				
Total	45 (16)	49 (16)	41 (15)	0.087
Symptoms	53 (21)	54 (20)	53 (23)	0.830
Activity	60 (19)	63 (19)	57 (20)	0.393
Impact	34 (19)	40 (20)	27 (16)	0.031*

Data presented as mean (SD). All: all participants; BMI: body mass index; FEV$_1$: forced expiratory volume in one second; FEV$_1$/FVC: ratio between forced expiratory volume in one second and forced vital capacity; FVC: forced vital capacity; kg/m^2: kilograms per metre squared; pred: predicted; SGRQ: St George's Respiratory Questionnaire; *significant difference between sexes.

Table 2. Glittre-ADL test performed with and without backpack.

	With BP Mean(SD)	W/out BP Mean(SD)	With BP Mean (SD)		W/out BP Mean (SD)		W/out BP – With BP Mean difference (95% CI)			Male - Female Mean difference (95% CI)	
	All	**All**	**Male**	**Female**	**Male**	**Female**	**All**	**Male**	**Female**	**With BP**	**Without BP**
Glittre-ADL, min	4.27 (1.84)	3.90 (1.44)	4.22 (1.44)	4.32 (2.24)	3.79 (1.19)	4.01 (1.70)	-0.37 (-0.59 to -0.15)*	-0.43 (-0.71 to -0.15)*	-0.31 (-0.68 to 0.06)	-0.11 (-1.30 to 1.09)	-0.23 (-1.16 to 0.71)
SpO_2, %	92 (6)	91 (7)	92 (6)	92 (5)	91 (8)	92 (6)	-0.95 (-2.27 to 0.37)	-1.19 (-3.54 to 1.16)	-0.67 (-1.85 to 0.52)	-0.24 (-3.85 to 3.38)	-1.15 (-5.78 to 3.48)
HR, bpm	118 (16)	116 (16)	120 (17)	116 (15)	118 (17)	114 (14)	-1.31 (-3.92 to 1.30)	-1.29 (-5.52 to 2.96)	-1.33 (-4.61 to 1.94)	4.04 (-6.26 to 14.33)	4.16 (-5.98 to 14.29)
Dyspnoea	4 (2)	4 (1)	4 (2)	3 (1)	4 (1)	3 (1)	-0.33 (-0.72 to 0.07)	-0.57 (-1.19 to 0.05)	-0.05 (-0.57 to 0.47)	1.06 (0.02 to 2.10)*	0.54 (-0.30 to 1.38)
RPE Legs	4 (3)	3 (2)	4 (3)	3 (3)	4 (2)	3 (2)	-0.28 (-0.72 to 0.17)	-0.24 (-0.99 to 0.51)	-0.32 (-0.85 to 0.22)	0.42 (-1.22 to 2.06)	0.49 (-0.78 to 1.77)
RPE Arms	2 (2)	2 (2)	3 (2)	2 (2)	2 (1)	2 (2)	-0.10 (-0.49 to 0.29)	-0.48 (-0.93 to -0.02)*	0.32 (-0.33 to 0.96)	0.50 (-0.67 to 1.67)	-0.29 (-1.39 to 0.81)

Definition of abbreviations: ADL: activity daily life; All: all participants; BP: backpack; bpm: beats per minute; HR: heart rate; min: minutes; RPE: rate of perceived exertion; SpO_2: oxygen saturation; W/out: Without; *significant difference between tests. Values for SpO_2, HR, Dyspnoea, RPE Legs and RPE Arms are from the end test.

Table 3. Relationship between Glittre-ADL tests and the six-minute walk test.

	Six minute walk test distance, meters		
	All	**Male**	**Female**
Glittre-ADL test time with BP, min	rho = -0.606	rho = -0.466	rho = -0.687
	p= <0.001	p= 0.033	p= 0.001
Glittre-ADL test time without BP, min	rho = -0.683	rho = -0.699	rho = -0.676
	p= <0.001	p= <0.001	p= 0.001

Definition of abbreviations: ADL: activity daily life; All: all participants; BP: backpack; Glittre-ADL: Glittre-activities of daily living test; rho: Spearman correlation coefficient.

Table 4. Characteristics of study participants who performed Glittre-ADL test with and without the backpack before and after pulmonary rehabilitation. (n=20).

Characteristic	Mean (SD)
Sex, M/F	13/7
Age, years	69 (7)
BMI, Kg/m^2	24 (5)
FEV_1, % predicted	50 (17)
FVC, % predicted	86 (24)
FEV_1/FVC	0.47 (0.14)
SGRQ	
Total	46 (14)
Symptoms	55 (26)
Activity	59 (17)
Impact	35 (17)

Data presented as mean (SD). BMI: body mass index; FEV_1: forced expiratory volume in one second; FEV_1/FVC: ratio between forced expiratory volume in one second and forced vital capacity; FVC: forced vital capacity; kg/m^2: kilograms per metre squared; pred: predicted; SGRQ: St George's Respiratory Questionnaire

Table 5. Responsiveness for Glittre-ADL test with and without the backpack after 8 weeks of pulmonary rehabilitation (n=20)

	Baseline	**Week 8**	**Baseline- week 8**	**Cohen's d**
	Mean (SD)	**Mean (SD)**	**Mean difference (95%CI)**	
Glittre-ADL test with BP, min	3.71 (0.88)	3.19 (0.60)	-0.52 (-0.81 to -0.22)*	0.82
Glittre-ADL test without BP, min	3.49 (0.67)	3.08 (0.54)	-0.41 (-0.63 to -0.18)*	0.86
6MWT distance, metres	479 (81)	549 (68)	49 (28 to 70)*	1.10

Definition of abbreviations: ADL: activity daily life; BP: backpack; min: minutes; 6MWT: six-minute walk test *significant difference between tests.

CHAPTER 5

GLITTRE-ADL TEST IN THREE LAPS AS AN ALTERNATIVE TO THE FIVE LAPS TEST

INTRODUCTION

The Glittre-ADL test (Skumlien et al., 2006) which measures the time taken to complete five laps of the course, has been proposed as the most promising and comprehensive test to evaluate functional capacity in patients with chronic obstructive pulmonary disease (COPD) (Bui et al., 2017). The course includes common tasks of everyday life such as standing from a chair, walking, climbing stairs and a grocery shelving task and involves 11 links to the International Classification of Functioning, Disability and Health framework (Skumlien et al., 2006; Correa et al., 2011; Bui et al., 2017).

The interest in the Glittre-ADL test has been increasing significantly (Bui et al., 2017) and more studies have been conducted in an attempt to elucidate the mechanisms involved in test performance (Cavalheri et al, 2011; Karloh et al., 2014; Tufanin et al., 2014; dos Santos et al., 2016; Souza et al., 2017). Karloh et al (Karloh et al., 2014) evaluated the physiological responses during Glittre-ADL test and observed that oxygen consumption reached a plateau after the third lap. Similar results were observed by Tufanin et al (Tufanin et al., 2014) evaluating cardiac, respiratory and metabolic adjustments of Glittre-ADL test. The authors reported progressive increase in all variables analysed until the third lap with no further increases in the remaining two laps. These findings suggest that the Glittre-ADL test might be adequately performed in three laps instead of five laps.

During the test, participants have to carry a backpack filled with 2.5 kg for women and 5.0 kg for man, and they are asked to perform the test as fast as possible (Skumlien et al., 2006). The study in the previous chapter demonstrated that the Glittre-ADL test performed without the backpack provoked the same physiological responses and symptoms for total group as the test performed with the backpack. Thus, this modification of performing the test with no backpack might make the test safer.

To the best of our knowledge, no study has directly evaluated the differences in symptoms, heart rate and oxygen consumption for the test performed in three and five laps both with and without the backpack. In addition, no study has investigated the responsiveness of a three-lap test after a pulmonary rehabilitation program.

This study aimed to compare the differences in performance of the Glittre-ADL test with and without the backpack in three and five laps in people with COPD. The primary aim was: i) to compare the differences in physiological responses and symptoms in performing the Glittre-ADL test performed with and without the backpack in three and five laps. The secondary aims were: i) to evaluate the relationship between Glittre-ADL test performed with and without the backpack in three and five laps and the six-minute walk test (6MWT); ii) to investigate the reliability of the Glittre-ADL test performed with the backpack in three laps; iii) to investigate the change in Glittre-ADL test performed with and without the backpack in three laps before and after a pulmonary rehabilitation program.

METHODS

Participants and study design

This was a cross-sectional study. Participants were recruited from referrals to outpatient pulmonary rehabilitation program at Royal Prince Alfred Hospital, Sydney,

Australia and to an outpatient pulmonary rehabilitation program at Federal University of Minas Gerais, Belo Horizonte, Brazil. Participants included in the study were: individuals with a diagnosis of COPD (GOLD, 2019) and stable over the past month. Participants were excluded if they presented with: concomitant cardiovascular, orthopaedic or neurological conditions that were likely to impair exercise performance; other significant pulmonary disease; body mass index over 35 kg/m^2; major psychiatric illness. Written informed consent was obtained from all participants. The trial was registered ANZCTR 12617000920392 and the study was approved by Ethics Committee from Australia (X14-0199 & HREC/14/RPAH/261) and Brazil (CAAE: 02288818.0.0000.5149).

Measures

Glittre-ADL test

The Glittre-ADL test has been previously described (Skumlien et al., 2006). In brief, participants stand up from a chair and then walk along a 10-metre track in which there are two steps to ascend and descend at the middle of the course. At the end of the track participants perform a shelving task of moving three weights of 1.0 kg each (one by one) from the top shelf to the bottom shelf and then down to the floor and then back to the bottom shelf and to the top shelf again. Participants then turn and walk back over the steps and sit down. This is considered one lap. Participants then immediately start the next lap. Technical details including dimensions of the degrees and adjustments of the shelves have been previously published (Skumlien et al., 2006). During the test, participants wear a backpack filled with 2.5 kg for women or 5.0 kg for men (Skumlien et al., 2006). The primary outcome of the test is the time taken to complete five laps. Participants are allowed to stop and rest during the test, but they are instructed to resume the test as soon as possible. In our study, the test was performed in five laps and

symptoms, heart rate and oxygen saturation were recorded for three and five laps. Similarly, the modified Glittre-ADL test without the backpack was also evaluated for three and five laps.

Other measures

Spirometry was performed according to standard procedures (Miller et al., 2005) using two calibrated portable spirometers, the (EasyOne spirometer for Australian participants (nnd Medical Technologies Inc., Andover, MA, USA) and the Koko (Ferraris Respiratory, USA) for the Brazilian participants. Obtained measures were compared to normative data (Gore et al., 1995; Pereira et al., 2007) and disease severity was classified according to GOLD criteria (GOLD, 2019).

Functional capacity was measured by the distance walked in the 6MWT (6MWD). The 6MWT (ATS, 2002; Butland et al., 1982; Cooper,1968) was performed according to previous published protocols (ATS, 2002).

Health-related quality of life (HRQoL) was measured by the St George's Respiratory Questionnaire (SGRQ) which has 53 items and assess three domains: symptoms, activity limitations and impact of disease (Jones et al., 1992).

Procedures

Participants attended for three data collection sessions over a 14-day period. On the first visit, demographic data of height, weight and age were recorded. The participants then performed spirometry, completed the SGRQ, and completed two 6MWTs with the best distance recorded for analysis. On the second visit, participants performed two Glittre-ADL tests with the backpack (test 1 and test 2) to eliminate the learning effect. On the third visit participants completed one Glittre-ADL test with the backpack and one without the backpack in random order. During all walk tests, oxygen saturation (SpO_2) and pulse rate were continuously monitored (Masimo Rad 5, Masimo

Corporation or Novametric, Respironics). Participants rested for 30 minutes between each test or until all parameters had returned to baseline levels. The time to complete five laps, symptoms, heart rate and SpO_2 were recorded before, at three and at five laps of both Glittre-ADL tests as the test outcomes. Symptoms were assessed using the modified 0-10 Scale (Borg ,1982) where dyspnoea and rate of perceived exertion (RPE) were obtained.

In a small sub-group the responsiveness of Glittre-ADL test performed with or without the backpack in three and five laps were tested. The participants attended an eight-week pulmonary rehabilitation program twice a week in which they performed 20 minutes of stationary cycling, 20 minutes of walking, 10 minutes of upper limb strength and endurance exercises and 10 minutes of lower limb strength and endurance exercises.

Sample size

The sample size calculation was based on a pilot study considering an equivalence between Glittre-ADL tests performed with and without the backpack in three or five laps. Equivalence of SpO_2 and heart rate, were chosen as the main outcomes, and the standard deviation (SD) of these measurements in the ten participants of the pilot study (3% for SpO_2, and 18 beats per minute for HR) were used in the calculation of sample size. A power of 0.90, an alpha of 5% and an equivalence limit of 3% for SpO_2 (Pierri et al., 1990), 14 beats per minute for heart rate (Jensen et al., 2013) were considered. The calculation determined a sample size of 22 participants for SpO_2 and 36 for heart rate.

Data analysis

Data are presented as mean and standard deviation, unless otherwise stated and the normality was verified by the Shapiro-Wilk test. Comparisons between Glittre-

ADL test times, symptoms, heart rate and SpO_2 in three or five laps for the tests performed with and without the backpack were conducted by ANOVA for repeated measures with one factor (tests). Post hoc analyses were performed by Bonferroni test. To verify the relationship between the Glittre-ADL tests performed in three and five laps and between the Glittre-ADL test time in three laps and the distance walked in the 6MWT, the Spearman correlation coefficient was used. The strength of the correlations was defined as < 0.20 as minimal or absent, from 0.25 to 0.50 as weak, from 0.50 to 0.75 as moderate, and from 0.75 to 1.0 as strong (Portney & Watkins, 2009). The level of significance was set at 5%. The Statistical Package for the Social Sciences (SPSS) v 15.0 (Chicago, IL, USA) was used for analyses.

RESULTS

Participant characteristics

The flow chart of study participants is presented in figure 2. Forty-one participants were recruited and all completed the comparison of Glittre-ADL with or without the backpack in three or five laps, and 16 completed the comparison of Glittre-ADL with or without the backpack in three or five laps before and after pulmonary rehabilitation. Table 1 presents demographic, anthropometric, spirometric, and clinical data of the participants. One participant was classified as GOLD 1, 18 as GOLD 2, 14 as GOLD 3, and 8 as GOLD 4.

Differences in performing Glittre-ADL test with and without the backpack in three and five laps

Table 2 shows the tests results for Glittre-ADL tests performed with and without the backpack in three and five laps. The time for the test was significantly shorter for both tests when performed in three laps instead of in five laps. There was not difference

in time for the test performed with or without the backpack in three laps. The Glittre-ADL test performed both with the backpack and without the backpack in three laps provoked the same symptoms and oxygen desaturation to the Glittre-ADL test performed in five laps. The heart rate was significantly lower for both Glittre-ADL tests performed in three laps.

Relationship between Glittre-ADL tests and six-minute walk test

Correlations between Glittre-ADL tests and 6MWT are presented in table 3. There were moderate correlations of the three and the five lap test (with and without the backpack) with the 6MWT (table 3).

Repeatability

There was a 0.33 minute decline in test time from test 1 to test 2 in the test performed with the backpack in three laps (2.72±1.20 vs 2.38±0.71 min; p=0.003) and a 0.47 minute decline in the test performed in five laps (4.62±1.92 vs 4.15±1.38 min; p=0.001). Both for the 3-lap test and the 5-lap test, the second test was completed more quickly, with a learning effect of 9% for both tests. When the test was performed for the third time, there was a 0.19 minute decline in test time performed in three laps (2.38±0.71 vs 2.19±0.66, p=0.006). When participants were divided into groups according to disease severity, it was observed that the further learning effect on test 3 only occurred in the participant group with very severe disease (n=8) (2.88±0.86 vs 2.69±0.83 min; p=0.025). No additional learning effect was evident on test 3 for the 5-lap test (4.15±1.38 vs 3.98±1.37, p=0.088).

Responsiveness

After eight weeks of pulmonary rehabilitation there were significant improvements in the Glittre-ADL test time performed in three or five laps both with or

without the backpack and in the 6MWD (Table 4). The effect size for all Glittre-ADL tests were moderate while the effect size for 6MWT was large.

DISCUSSION

The findings of this study demonstrated that: 1) The Glittre-ADL test performed both with the backpack and without the backpack in three laps provoked the same symptoms and oxygen desaturation as the Glittre-ADL test performed in five laps; 2) The heart rate was significantly lower for both Glittre-ADL tests performed in three laps; 3) Glittre-ADL test in three or five laps both with and without the backpack were moderately correlated with the 6MWT; 4) Glittre-ADL test performed in three laps presented learning effect even when it was performed for the third time for more severe participants; 5) The Glittre-ADL test performed in three or five laps both with and without the backpack was responsive to change following a pulmonary rehabilitation program.

The Glittre-ADL test presents the advantages of being a test that is more representative of functional activities (Skumlien et al., 2006; Skumlien et al., 2008; Bui et al., 2017), assessing both the function of arms and legs in common daily activities (Bui et al., 2017), and demonstrating good responsiveness to pulmonary rehabilitation (Skumlien et al., 2006). For all these reasons, the interest in the test to assess patients with COPD has been increasing (Skumlien et al., 2006: Skumlien et al., 2008; Correa et al., 2011; Karloh et al., 2014; Tufanin et al., 2014; de Araujo et al., 2015; dos Santos et al., 2016; Calik-Kutukcu et al., 2017).

The main outcome of the test is the time taken to complete 5 laps (Skumlien et al., 2006), however, two studies (Karloh et al., 2014; Tufanin et al., 2014) previously demonstrated that after the third lap there is a stabilization of the physiological

responses in patients with COPD, however, these studies did not directly aim to evaluate this outcome. Taking into account that a shorter test is more practical and demands less time, saving patients' and clinicians' time, it is important to evaluate whether Glittre-ADL test can be performed as a 3-lap test. Thus, this study directly assessed the differences in physiological responses and symptoms for the test performed in three or five laps. In addition, the previous chapter demonstrated that the test performed without the backpack provoked the same physiological responses and symptoms as the test performed with the backpack. Therefore, this study also investigated the differences in the performance of three and five laps test without the backpack.

As expected, the time to complete the test was significantly shorter for the 3-lap tests compared to the 5-lap test. In addition, there was no difference in time to complete the test performed with or without the backpack in three laps, however, the backpack seems to make a difference for the 5-lap test, making the test longer. The Glittre-ADL test performed both with the backpack and without the backpack in three laps provoked the same symptoms and desaturation to the Glittre-ADL test performed in five laps, indicating that the test can be performed in three laps instead of five laps. Similar results were showed by previous authors (Karloh et al., 2014; Tufanin et al., 2014), who observed no further increases in symptoms or decline in oxygen saturation after lap three of the 5-lap test. The heart rate observed in our study for the tests performed in three laps were significantly lower than for the tests performed in five laps for both the test performed with the backpack (3 beats/minute lower) and without the backpack (2 beats/minute lower). Although statistically different, the difference is small and unlikely to be of clinical relevance.

The 6MWT was chosen as the comparison test for the Glittre-ADL tests with and without the backpack in three or five laps because it is the most widely used test to assess functional capacity in people with COPD (Holland et al., 2014). The validity of the Glittre-ADL test was previously demonstrated by comparisons with the 6MWT, which showed strong correlations with the distance walked in the 6MWT ($r=-0.82$, $p<0.001$) (Skumlien et al., 2006). In our study, the Glittre-ADL test with the backpack and without the backpack in three and five laps, also showed a moderate correlation with the 6MWD.

The Glittre-ADL test performed both with the backpack and without the backpack in three laps provoked the same symptoms and oxygen desaturation as the Glittre-ADL test performed in five laps. These findings suggest that the 3-lap test could be an alternative to the 5-lap test, which would reduce overall testing time and thus be a more acceptable test for busy clinicians to perform in patient assessments. However, the 3-lap test had a further learning effect when performed for a third time which was not evident in the 5 lap-test. When the groups were divided according to disease severity, the further learning effect in the 3-lap test was only evident in the participant sub-group with very severe disease, which suggests that two 3-lap test may be sufficient at assessment in all COPD patients, except those with very severe disease. Further studies evaluating the learning effect in the 3-lap test should be conducted to confirm whether the learning effect is evident on a third test when participants are naive to the Glittre-ADL test.

The original Glittre-ADL test (i.e. performed with the backpack in five laps) was shown to be responsive to pulmonary rehabilitation after 24 sessions of pulmonary rehabilitation in 60 patients with mild to very severe COPD and the minimal important difference was reported as 0.38 minutes. (Gullart et al., 2018). Our study provides

further evidence of the responsiveness of the 5-lap Glittre-ADL test with backpack to 16 session of pulmonary rehabilitation and extends this finding by demonstrating the responsiveness to pulmonary rehabilitation of the 3-lap Glittre-ADL test with and without the backpack, as well as the 5-lap Glittre-ADL test without the backpack. Participants in our study achieved the minimal important difference in the Glittre-ADL test (5-laps with backpack) after 16 sessions of pulmonary rehabilitation. Further studies to determine the minimal important difference for Glittre-ADL tests performed in three laps with and without the backpack should be conducted. The effect size in response to pulmonary rehabilitation observed for the 6MWT was larger than the effect size observed for the Glittre tests. The smaller effect size for the Glittre-ADL tests is most likely due to these tests assessing at least ten activities such as, walking, climbing, standing, sitting, etc. compared to the 6MWT only assessing one functional activity (walking).

A limitation of this study is that the Glittre-ADL test was not stopped after three laps. The test performance may have been different if participants knew that the test was only three laps. However, participants were monitored and encouraged to do their best throughout. In addition, no direct measures to evaluate the metabolic and ventilatory responses during the tests were made.

CONCLUSION

In conclusion, the three lap Glittre-ADL test both with and without the backpack provoked the same symptoms and oxygen desaturation as the 5-lap test, except for heart rate that was significantly higher for the 5-lap test. The heart rate difference was small and unlikely to be of clinical relevance. Thus, it is reasonable to suggest that the 3-lap

Glittre-ADL test may be a more practical alternative to the 5-lap test, while still remaining a good test of functional capacity for activities of daily living.

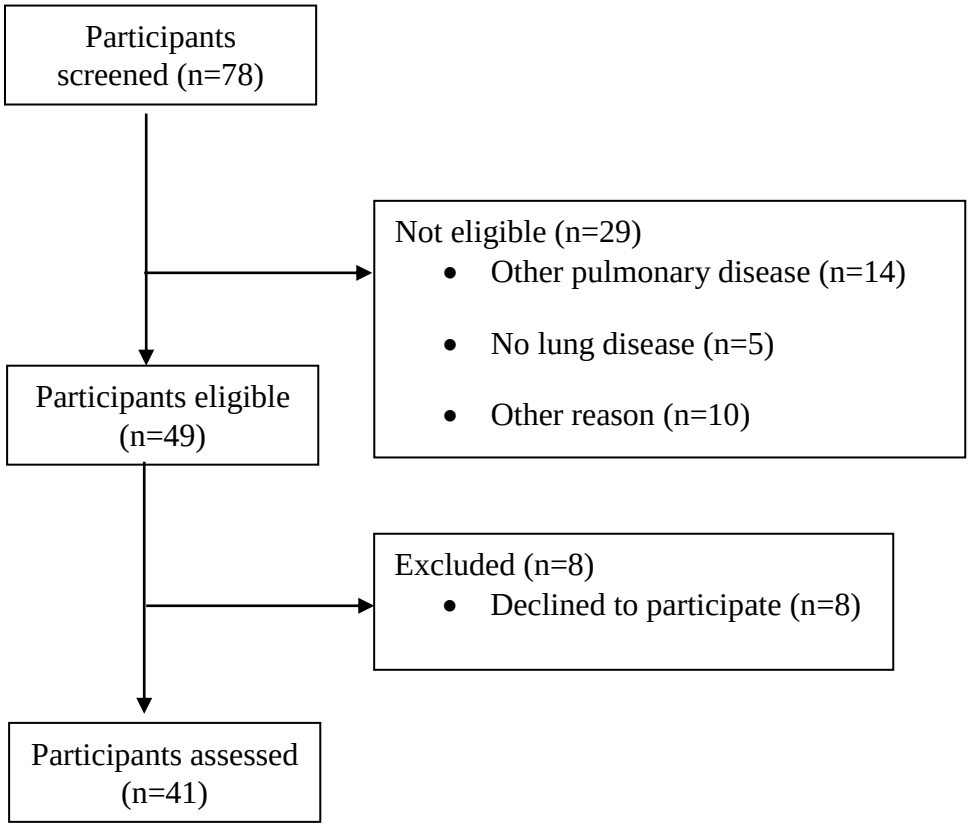


Figure 1. Flow of participants through the study.

Table 1. Characteristics of study participants (n=41).

Characteristic	**Baseline participants** **n=41** **Mean (SD)**	**Post rehab participants** **n=16** **Mean (SD)**
Sex, M/F	24/17	12/4
Age, years	68 (7)	69 (7)
BMI, Kg/m^2	24 (5)	24 (6)
FEV$_1$, % predicted	46 (17)	50 (18)
FVC, % predicted	75 (23)	86 (27)
FEV$_1$/FVC	0.48 (0.13)	0.47 (0.15)
SGRQ		
Total	52 (16)	48 (15)
Symptoms	58 (23)	55 (29)
Activity	63 (22)	60 (19)
Impact	40 (20)	38 (18)

Data presented as mean (SD). BMI: body mass index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; FEV_1/FVC: ratio between forced expiratory volume in one second and forced vital capacity; kg/m^2: kilograms per metre squared; pred: predicted; rehab: rehabilitation; SGRQ: St George's Respiratory Questionnaire

Table 2. Glittre-ADL test performed with and without backpack in three and five laps.

	With BP 3 laps Mean (SD)	With BP 5 laps Mean (SD)	Without BP 3 laps Mean (SD)	Without BP 5 laps Mean (SD)	F value	p value
Glittre-ADL test, min	2.19 (0.66)	3.98 (1.37)*	2.14 (0.63)†	3.73 (1.23)*†#	$F_{(1.658,66.335)} = 181.749$	<0.001
SpO_2, %	90 (7)	90 (6)	90 (7)	89 (8)	$F_{(2.067,78.537)} = 2.811$	0.064
HR, bpm	110 (15)	113 (15)*	112 (14)	115 (15)*#	$F_{(2.173,82.590)} = 4.933$	0.008
Dyspnoea	4 (2)	5 (2)	4 (2)	4 (2)	$F_{(3,117)} = 3.581$	0.016
RPE Legs	3 (2)	3 (2)	3 (2)	3 (2)	$F_{(2.243,87.475)} = 1.085$	0.358
RPE Arms	2 (2)	2 (2)	2 (2)	2 (2)	$F_{(2.390,93.202)} = 1.389$	0.254

Definition of abbreviations: ADL: activity daily life; BP: backpack; bpm: beats per minute; HR: heart rate; min: minutes; RPE: rate of perceived exertion; SpO_2: oxygen saturation; F = F Statistics; p value: for the repeated measures ANOVA. Post hoc Bonferroni test was used to determine where the differences were between tests. Values for SpO_2, HR, Dyspnoea, RPE Legs and RPE Arms are from the end test

* Significant difference ($p < 0.001$) compared with BP 3 laps

† Significant difference ($p < 0.001$) compared with BP 5 laps

Significant difference ($p < 0.001$) compared with BP 3 laps

Table 3. Relationship between Glittre-ADL tests and the six-minute walk test.

Glittre-ADL test	**6MWT**	**Correlation** **Spearmans' rho (p-value)**
With BP 3 laps, min	6MWD	-0.607; (p<0.001)
With BP 5 laps, min	6MWD	-0.622; (p<0.001)
Without BP 3 laps, min	6MWD	-0.717; (p<0.001)
Without BP 5 laps, min	6MWD	-0.733; (p<0.001)

Definition of abbreviations: ADL: activities of daily living; BP: backpack; min: minutes; rho: Spearman correlation coefficient; 6MWT: six-minute walk test; 6MWD: six-minute walk distance.

Table 4. Responsiveness to pulmonary rehabilitation of the Glittre-ADL test performed with and without backpack in three and five laps (n=16)

	Baseline **Mean (SD)**	**Week 8** **Mean (SD)**	**Baseline- week 8** **Mean difference (95%CI)**	**Cohen's d**
Glittre-ADL test with BP 3 laps, min	2.18 (0.39)	1.96 (0.37)	-0.22 (-0.40 to -0.04)*	0.76
Glittre-ADL test with BP 5 laps, min	3.72 (0.95)	3.25 (0.63)	-0.47 (-0.86 to -0.08)*	0.64
Glittre-ADL test without BP 3 laps, min	2.09 (0.33)	1.88 (0.31)	-0.21 (-0.37 to -0.04)*	0.67
Glittre-ADL test without BP 5 laps, min	3.58 (0.66)	3.18 (0.54)	-0.40 (-0.68 to -0.12)*	0.76
6MWD, metres	461 (77)	507 (87)	46 (21 to 70)*	1.00

Definition of abbreviations: ADL: activity daily life; BP: backpack; *significant difference between tests

CHAPTER 6

GLITTRE ENDURANCE TEST: A NEW TEST TO ASSESS THE FUNCTIONAL CAPACITY OF INDIVIDUALS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE

INTRODUCTION

The Glittre-ADL test (Skumlien et al., 2006) has been proposed as the most promising and comprehensive test to evaluate functional capacity in individuals with chronic obstructive pulmonary disease (COPD) (Bui et al., 2017). The test is valid (Skumlien et al., 2006; Karloh et al., 2014), reliable (Skumlien et al., 2006; dos Santos et al., 2016; Jose & Dal Corso, 2015), presents good responsiveness (Skumlien et al., 2006), and different from the most used tests to assess functional capacity (Holland et al, 2014), it includes the assessment of upper limb activities, which are also important for daily functional tasks.

The outcome of the test is the time taken to complete five laps and the course includes functional activities such as sit down and stand up from a chair, walking, climbing stairs, and bending down and bending over to perform a shelving task (Skumlien et al., 2006; Correa et al., 2011). While the test might be a useful measure, often people with COPD after a pulmonary rehabilitation program, cannot significantly improve the speed with which they perform activities, but may be able to perform activities for longer, with less breathlessness and fatigue.

Previously, it has been shown that the endurance capacity, often measured by the Endurance Shuttle Walk Test (ESWT) is a more sensitive measure of change in functional capacity after pulmonary rehabilitation (Eaton et al., 2006; Revill et al., 1999). In this context, this study aimed to evaluate if a modification of the Glittre ADL-

test to better reflect endurance capacity for functional tasks, is a good measure of functional capacity in individuals with COPD.

The primary aim of this study was to develop a Glittre Endurance test to measure endurance capacity for functional tasks, including upper limb tasks. The secondary aims were: i) to investigate the repeatability of the Glittre Endurance test; ii) to compare the relationship between the Glittre Endurance test and other field tests; iii) to investigate the responsiveness to change of the Glittre Endurance test when performed before and after a pulmonary rehabilitation program.

METHODS

Participants and study design

This was a cross-sectional study. Participants were recruited from referrals to an outpatient pulmonary rehabilitation program at Royal Prince Alfred Hospital, Sydney, Australia and to an outpatient pulmonary rehabilitation program at Federal University of Minas Gerais, Belo Horizonte, Brazil. Participants were included in the study if they had a diagnosis of COPD (GOLD, 2019) and were stable over the past month. Exclusion criteria were: concomitant cardiovascular, orthopaedic or neurological conditions that were likely to impair exercise; other significant pulmonary disease; body mass index over 35 kg/m^2; major psychiatric illness. Written informed consent was obtained from all participants. The trial was registered ANZCTR 12617000920392 and was approved by Ethics Committee from Australia (X14-0199 & HREC/14/RPAH/261) and Brazil (CAAE: 02288818.0.0000.5149).

Development of the Glittre Endurance test

The Glittre Endurance test was based on the Glittre-ADL test (Skumlien et al., 2006). However, two modifications were made to better reflect the endurance capacity

(Revill et al., 1999) and make the test safer. These modifications were allowing participants to perform the test for as long as possible (rather than the time taken for 5 laps as in the Glittre-ADL test) and the test was performed without the backpack, as chapter 4 demonstrated that the Glittre-ADL test performed without the backpack provoked the same physiological responses and symptoms as the test performed with the backpack.

The 10-metre course was the same as in the Glittre-ADL test. Technical details including dimensions of the stairs and adjustments of the shelf heights have been previously published (Skumlien et al., 2006). The speed with which the test was performed was based on the participant's initial Glittre-ADL test performed without the backpack (see below for the protocol development for determining test speed). An audio signal software to control the participant's speed during the test was developed. At the sound of a buzzer the participants were asked to stand from the chair, walk until the steps, climb the steps, walk again towards the shelf and on the shelf to move the weight of 1kg each, one by one, from the top shelf down to the bottom shelf, and then, to the floor. Participants needed to reach this point in the test by the time of the next buzzer. If they reached this point before the buzzer they were asked to wait until the buzzer before returning the weights, one by one, from the floor to the bottle shelf, and then, to the top shelf again, turn, walk back over the steps and sit down on the chair before the next buzzer. This was considered one lap.

The participants received the instruction to perform the test for as long as possible. Similar to ESWT, the maximum time of the test was considered 20 minutes due to practical clinical reasons, however, participants were not informed of this limit, unless they achieved the limit of the test.

Participants were instructed to do their maximum and to perform the test until they felt too tired or breathless to continue, at which point the test was ended. The assessor could also end the test if the participant could not keep pace with the buzzer. The criteria for terminating a test was based on the following (i.e. behind time for a lap):

1. All weights were only on the bottom shelf when the buzzer sounded (all weights should be on the floor at this time point). If this occurred, the participant was encouraged to increase their speed.
2. If the participant could not then increase the speed and was 0.5 metres from the chair when the buzzer sounded (participant should be sitting down when the buzzer sounded).

These criteria were considered as failure to complete a lap in the designated time.

Determining the speed for the Glittre Endurance test

For the development of the Glittre Endurance test an appropriate speed, individualised and based on the participant's previous best Glittre-ADL test without backpack, was required. The aim was to find the percent of the speed of the Glittre-ADL test without the backpack that resulted in a Glittre Endurance test time of between six to 10 minutes. This Glittre Endurance test time range was chosen in order for this test to be most responsive to change after an intervention such as pulmonary rehabilitation (Borel, Provencher, Saey & Maltais, 2012). For the first nine participants, the intensity was set at 90% of the time to perform one lap of the Glittre-ADL test performed without the backpack. However, 33.3% of the participants achieved the ceiling effect (20 minutes) of the test. For these three participants, the Glittre Endurance test was repeated at a speed set at 95% of the speed to perform one lap of the Glittre-ADL test without the backpack. The three participants were still able to complete 20 minutes, the maximum time of the test. For this reason, for the next 43 participants, the

protocol was altered to an intensity of 100% of the time to perform one lap of the Glittre-ADL test without the backpack.

Other measures

Spirometry was performed using a calibrated portable spirometer (Easy One spirometer; nnd Medical Technologies Inc., Andover, MA, USA) or (Koko, Ferraris Respiratory, USA) according to standard procedures (Miller et al., 2005). Obtained measures were compared to normative data (Gore et al., 1995; Pereira et al., 2007) and disease severity was classified according to GOLD criteria (GOLD, 2019).

Functional capacity was measured by the distance walked on the six-minute walk test (6MWT), the time to complete the Glittre-ADL test, the time to complete the Glittre-ADL test without the backpack, and the distance walked in the ESWT, which were performed according to previous published protocols (Skumlien et al., 2006; Revill et al., 1999).

Health-related quality of life (HRQoL) was measured by the St George's Respiratory Questionnaire (SGRQ), which has 53 items and assesses three domains: symptoms, activity limitations and impact of disease (Jones et al, 1992).

Procedures

Participants attended for four data collection sessions over a 14-day period. On the first visit, demographic data such as height, weight and age were recorded. The participants then performed spirometry, completed the SGRQ, and completed two 6MWTs with the best distance recorded for analysis. On the second visit, participants performed two Glittre-ADL tests with the backpack to eliminate the learning effect and one ESWT. On the third visit, participants completed one Glittre-ADL test with the backpack and one without the backpack, in random order. The order of the tests was randomized in blocks by a computer program (https://www.random.org/). At this day,

they also performed the second ESWT. On the fourth visit, participants performed two Glittre Endurance tests. Participants rested for 30 minutes between each test or until all parameters had returned to baseline levels. The distance walked on 6MWT, the time to complete five laps of all Glittre-ADL tests, the time to perform ESWT and the time to perform Glittre Endurance test were recorded as the test outcomes. During all tests, oxygen saturation (SpO_2) and pulse rate were continuously monitored (Masimo Rad 5, Masimo Corporation or Novametric, Respironics). Dyspnoea and rate of perceived exertion (RPE) were assessed before and immediately at the end of each test using the modified 0-10 Scale (Borg, 1982).

Repeatability of the Glittre Endurance test

The repeatability of the Glittre Endurance test was assessed by the participants performing two tests under the same conditions within 30 minutes of each other.

Responsiveness of the Glittre Endurance test

In a sub-group, the responsiveness to pulmonary rehabilitation of Glittre Endurance test was evaluated. The participants attended an eight-week pulmonary rehabilitation program twice a week in which they performed 20 minutes of stationary cycling, 20 minutes of walking, 10 minutes of upper limb strength and endurance exercises and 10 minutes of lower limb strength and endurance exercises.

Sample size

Forty participants were required to have an 80% chance of detecting, as significant at the 5% level an increase in Glittre Endurance test time after pulmonary rehabilitation of 180 seconds, assuming a standard deviation (SD) of 492 seconds based on the first ten participants of the study that perform the test at 100% intensity. An improvement in Glittre Endurance test time after pulmonary rehabilitation of 180 seconds was chosen as this is the proposed minimal important difference for the ESWT

(Pepin et al., 2012; Holland et al., 2014), which has similar construct to the Glittre Endurance test.

Data analysis

Data are presented as mean and standard deviation, unless otherwise stated and the normality was verified by the Shapiro-Wilk test. Comparisons between Glittre Endurance outcomes at 90% and 100% intensity were performed by independent group *t*-tests. Comparisons between first and second Glittre Endurance tests and between Glittre Endurance tests before and after pulmonary rehabilitation were performed using paired *t*-tests. To verify the relationship between the Glittre Endurance-test and the Glittre-ADL tests time, the ESWT, and the distance walked on 6MWT, Spearman's correlation coefficient was used. The strength of the correlations was defined as < 0.20 as minimal or absent, from 0.25 to 0.50 as weak, from 0.50 to 0.75 as moderate, and from 0.75 to 1.0 as strong (Portney & Watkins, 2009). The level of significance was set at 5%. The Statistical Package for the Social Sciences (SPSS) v 15.0 (Chicago, IL, USA) was used for analyses.

RESULTS

Participant characteristics

The flow chart of study participants is presented in figure 1. Fifty-two participants were recruited and completed the assessments. Participants were divided into two groups to test development of the Glittre Endurance test as follow: Group A (n=9) participated in the development of the protocol using 90% of the speed to complete one lap of the Glittre-ADL test performed without the backpack. Sub-Group A (n=3) consisted of three participants who achieved the ceiling effect (20 minutes) at 90% intensity, and for this reason, performed the test again at 95% of the speed to

complete one lap of the Glittre-ADL test performed without the backpack. Group B (n=43) performed the test at 100% of the speed to complete one lap of the Glittre-ADL test performed without the backpack. Data from this group was also used to evaluate the repeatability of the Glittre Endurance test. Group C (n= 17) completed the comparison of the Glittre Endurance test before and after pulmonary rehabilitation. Table 1 presents demographic, anthropometric, spirometric, and clinical data of the participants. Three participants were classified as GOLD 1, 22 as GOLD 2, 17 as GOLD 3, and 10 as GOLD 4.

Development of the Glittre Endurance test

All participants (n=52) were involved on the development of the Glittre Endurance Test. The endurance capacity was defined as the maximal duration of the test at the set speed obtained by the Glittre-ADL test performed without the backpack. The physiological response and symptoms at the end of the Glittre Endurance test at 90%and 100% intensities are presented in Table 2. There was a reduction in Glittre Endurance time as the intensity increased. In addition, there were no significant differences in physiological responses and symptoms between intensities. Three participants achieved ceiling effect at 90% intensity, and for this reason, performed the test at 95% intensity, however, all of these participants were still able to complete the maximal test time of 20 minutes. Only one participant achieved the ceiling effect (20 minutes) in the test performed at 100% intensity. This participant later performed the test at 110% intensity, and the test was terminated at 12.10 minutes because the participant could not keep up with the speed.

Repeatability

The repeatability of the test was assessed for the test performed at 100% intensity and is presented in table 3. Participants showed an improvement in Glittre

Endurance time when test 2 was compared to test 1, which equated to a 14.6% increase in test time, indicating a learning effect. The repeatability between test 1 and 2 was moderate with an interclass correlation of 0.70 with a confidence interval from 0.49 to 0.82, $p<0.0001$ for single measures.

Relationship between Glittre Endurance test and other field tests

Table 4 shows the relationship between Glittre Endurance test time and the field tests: Glittre-ADL test, Glittre-ADL test performed without the backpack, ESWT, and 6MWT. There was no relationship between the Glittre Endurance test and any of the other field tests.

Responsiveness

Seventeen participants completed the Glittre Endurance test before and after pulmonary rehabilitation. Participant characteristics are presented in Table 5. After eight weeks of pulmonary rehabilitation there was a significant improvement in the Glittre Endurance test time (Table 6). The effect size for all field tests was large, however the effect size for Glittre Endurance test was higher compared with the original Glittre-ADL test performed in five laps and the modified version performed without the backpack.

DISCUSSION

The findings of this study were: 1) a test to assess the endurance capacity for functional tasks, the Glittre Endurance test, was developed; 2) there was a learning effect evident when a second Glittre Endurance test was performed; 3) the Glittre Endurance test did not correlate with any other field tests; 4) the Glittre Endurance test performed at 100% intensity was responsive to change following a pulmonary rehabilitation program.

The most used test to assess functional capacity of people with COPD is the 6MWT (Holland et al., 2014), which is self-paced and time limited. The incremental shuttle walk test (ISWT) was developed (Singh et al., 1992) with the aim to create a more standardised test of peak capcity and reducing the influence of motivation and encouragement The ESWT was developed to evaluate endurance capacity for the functional task of walking (Revill et al., 1999). The ISWT and ESWTare externally paced and while ISWT is an incremental test, the ESWT is at a constant pace where participants have to sustain a level of exertion until being limited by symptoms (Revill et al., 1999). However, these tests only assess walking activity and do not include the assessment of upper limbs or other functional tasks, such as stair climbing, which are also important for daily life. The Glittre-ADL test was developed (Skumlien et al., 2006) to include the assessment of upper limbs as well as other functional activities. Although the Glittre-ADL test is a measure of functional capacity, the outcome of the test is the time taken to complete five laps, so in order to improve performance on the Glittre-ADL test, participants need to perform the test faster. Since participants may not be able to perform activities faster but may be able to perform them for longer after pulmonary rehabilitation (Wootton et al., 2014) tests of endurance capacity have demonstrated greater sensitivity to change after an intervention like pulmonary rehabilitation (Eaton et al., 2006; Revill et al., 1999) compared with incremental tests or time-limited tests., The Glittre Endurance Test was developed as a modification to the Glittre-ADL test in order to evaluate the endurance capacity of participants to perform daily tasks.

The Glittre Endurance test is performed at a constant speed, based on the participant's speed in the Glittre-ADL test without the backpack, and is externally paced. The Glittre Endurance test assesses functional upper and lower limb endurance

capacity through different activities, which are important for mobility and participation in daily life. The test only requires a 10-metre track and a small amount of equipment (Bui, et al., 2017). The test showed greater response to change following pulmonary rehabilitation compared with the original Glittre-ADL test.

Initially, the intensity for the Glittre Endurance test was set at 90% of the speed to perform one lap of the Glittre-ADL test performed without the backpack. However, three participants (33.3%) performed the maximum 20 minutes of the test. The three participants who achieved the maximum test time performed the test at 95% intensity, and still completed 20 minutes. For this reason, the test was set at 100% of the speed to perform one lap of the Glittre-ADL without the backpack. The test time for the test performed at 100% intensity was shorter than the test time performed at 90% intensity. For clinical purposes, a shorter test is preferable and increases the margin for better showing change following the pulmonary rehabilitation (Revill et al., 1999).

The Glittre Endurance test developed in this study is proposed as a test to evaluate the endurance capacity for functional tasks using the same construct as the ESWT. The development of the ESWT was based on the ISWT and tested in three different intensities: 75%, 85%, and 95% of participants' maximum ISWT performance. The 85% intensity was chosen as the most suitable intensity for the ESWT (Revill et al., 1999). The Glittre Endurance Test was based on the performance of the Glittre-ADL test without the backpack and it was tested at two different intensities: 90% and 100% with the aim of the test being completed between 6 to 10 minutes prior to any intervention. Our results showed that the test at 100% intensity of participants' speed for one lap of Glittre-ADL test without the backpack achieved a test duration of approximately 8.5 minutes. The test intensities evaluated in this study were higher than those tested by Revill and colleagues in developing the ESWT (Revill et al.,1999). The

difference in intensities is most likely related to the fact that the ESWT was based on an externally paced test, i.e. the ISWT, whereas the Glittre Endurance test was based on a self-paced test, i.e. the Glitrre-ADL without backpack. In a self-paced time-limited test the test performance may be influenced by the individuals' judgement of an appropriate pace and self-imposed work rate (Guyatt et al, 1984).

Similar to other field tests (Holland et al., 2014), a significant improvement was observed when the Glittre Endurance test was performed for the second time, suggesting a learning effect. This was despite the second test being performed on the same day as the first test and up to a maximum interval of three days after Glittre-ADL test without backpack.

The Glittre Endurance test did not correlate with Glittre-ADL test or the modified Glittre-ADL test without backpack or the 6MWT, confirming that these tests evaluate different constructs. In addition, the Glittre Endurance test did not correlate with ESWT even though both tests are supposed to measure endurance capacity. Despite evaluating similar constructs, the ESWT evaluates only walking endurance capacity while Glittre Endurance test evaluates the capacity of the individual to sustain exertion for multiple functional activities. This difference might explain the absence of correlation between tests.

Our study supports previous studies that have shown that endurance capacity is a more sensitive measure of change in functional capacity following pulmonary rehabilitation (Eaton et al., 2006; Revill et al., 1999). The Glittre Endurance test was highly responsive to change and had a larger effect size (d=0.98) when compared with the Glittre-ADL test (d=0.83), Glittre-ADL test performed without the backpack (d=0.80) and the 6MWT (d=0.87). The likely reason for the lower responsiveness of the self-paced tests was that to show improvement participants needed to increase speed.

The effect size observed for Glittre Endurance Test was lower than that for the ESWT (d=1.33). The greater improvement in ESWT might have occurred because the assessment involved only one functional activity (walking) while Glittre Endurance test involved multiple activities activities (sitting, standing, walking, stair climbing, reaching, lifting, putting down objects, grasping and releasing) making the Glittre Endurance test more complex and difficultcompared to the ESWT.

A limitation of this study was that the sample size for the responsiveness of the Glittre Endurance test to pulmonary rehabilitation was lower than the calculated sample size. Despite this, the Glittre Endurance test was shown to be highly responsive to pulmonary rehabilitation. In addition, the study did not evaluate whether there was a learning effect for the Glittre-ADL test performed without the backpack. If a learning effect exists, the performance of two Glittre-ADL tests without the backpack would be necessary prior to the Glittre Endurance test in order to select the appropriate speed for the endurance test. Similar to most endurance tests, the speed for the Glittre Endurance test is individualised therefore making comparisons between individulas difficult.

CONCLUSION

In conclusion, the Glittre Endurance test is potentially an appropriate test to assess endurance capacity for functional tasks that are important for daily life in people with COPD. The Glittre Endurance test demonstrated good responsiveness to pulmonary rehabilitation confirming that this test is a sensitive measure of change in functional capacity.

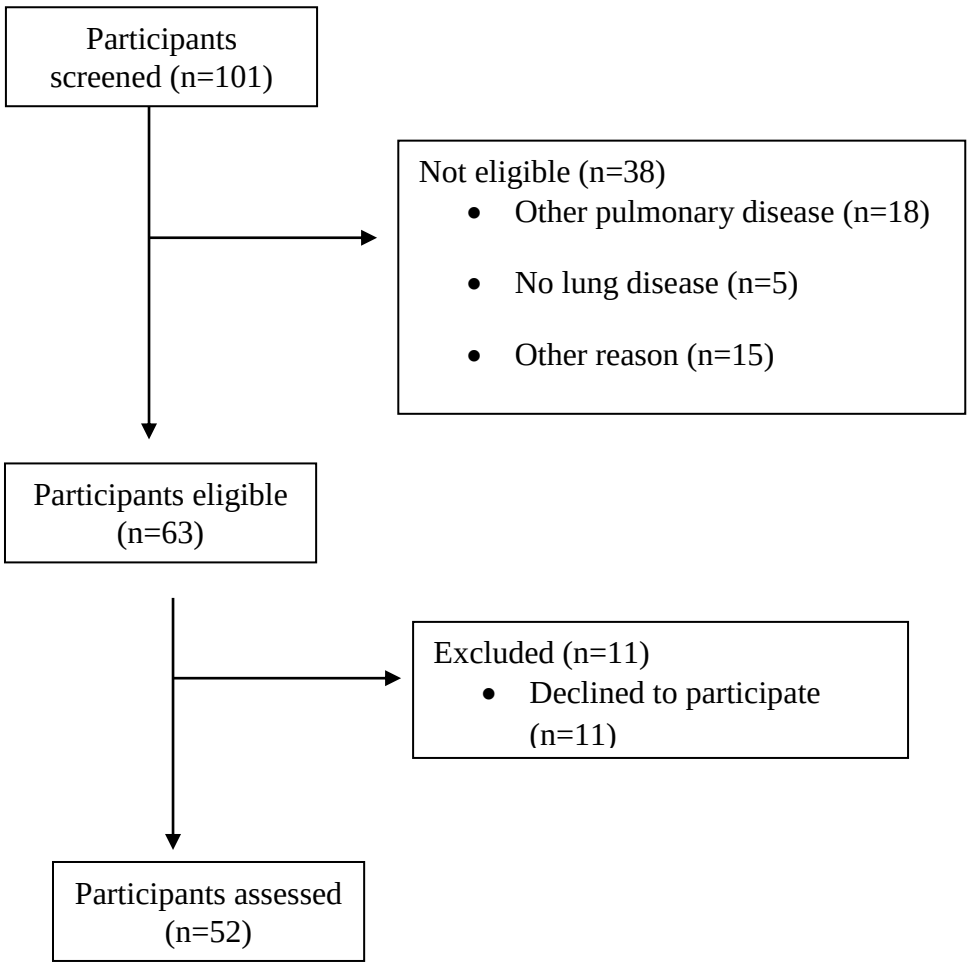


Figure 1. Flow of participants through the study.

Table 1. Characteristics of study participants i.e Group A and Group B (n=52).

Characteristic	Group A (n=9)	Sub-Group A (n=3)	Group B (n=43)
M:F	3:6	1:2	24:19
Age, years	70 (5)	68 (6)	68 (7)
BMI, Kg/m^2	25 (4)	26 (5)	24 (5)
FEV_1, % predicted	50 (19)	48 (31)	47 (18)
FVC, % predicted	82 (24)	91 (40)	78 (24)
FEV_1/FVC	0.49 (0.12)	0.41 (0.09)	0.48 (0.13)
SGRQ			
Total	40 (15)	40 (22)	48 (16)
Symptoms	52 (17)	51 (24)	54 (24)
Activity	55 (20)	61 (32)	63 (19)
Impact	28 (15)	24 (18)	37 (20)

Data presented as mean (SD). BMI: body mass index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; FEV_1/FVC: ratio between forced expiratory volume in one second and forced vital capacity; kg/m^2: kilograms per metre squared; pred: predicted; SGRQ: St George's Respiratory Questionnaire

Table 2. Physiological response and symptoms at the end of the Glittre Endurance test

	90% Glittre Endurance n=9	**100% Glittre Endurance n=43**	**p value**
Lap time, sec	25 (12)	22 (7)	0.364
Glittre Endurance test time, min	12.92 (5.89)	8.48 (4.29)*	0.049
SpO_2, %	93 (4)	90 (8)	0.231
HR, bpn	130 (17)	122 (15)	0.069
Dyspnoea	4 (3)	5 (2)	0.282
RPE Legs	3 (3)	3 (2)	0.261
RPE Arms	2 (3)	3 (2)	0.339

Definition of abbreviations: bpm: beats per minute; HR: heart rate; min: minutes; RPE: rate of perceived exertion; sec: seconds; SpO_2: oxygen saturation; Values for SpO_2, HR, Dyspnoea, RPE Legs and RPE Arms are from the end test**;** * Significant difference ($p < 0.05$) compared with 90% Glittre Endurance.

Table 3. Repeatability of the Glittre Endurance test (n=43)

			Mean difference (95% CI)
	Test 1	**Test 2**	**Test 1 – Test 2**
Lap time, sec	22 (7)	22 (7)	-
Test time, min	7.04 (4.24)	8.07 (4.24)	1.03 (0.005 to 2.06)*
SpO_2, %	90 (7)	89 (8)	-1.44 (-2.41 to -0.47)*
HR, bpm	118 (14)	122 (16)	3.32 (-0.07 to 6.71)
Dyspnoea, score	4 (2)	5 (2)	0.21 (-0.13 to 0.55)
RPE Legs, score	3 (2)	3 (2)	-0.03 (-0.42 to 0.35)
RPE Arms, score	2 (2)	2 (2)	0.27 (-0.02 to 0.55)

Definition of abbreviations: bpm: beats per minute; HR: heart rate; min: minutes; RPE: rate of perceived exertion; sec: seconds; SpO_2: oxygen saturation; Values for SpO_2, HR, Dyspnoea, RPE Legs and RPE Arms are from the end test**;** * Significant difference ($p < 0.05$) test 1 compared with test 2

Table 4. Relationship between Glittre Endurance test and field tests (n=43)

	Glittre Endurance test time, minutes
Glittre-ADL test time, min	rho = -0.057; p= 0.715
Glittre-ADL test time without BP 5 laps, min	rho = 0.166; p= 0.288
ESWT, min	rho = 0.281; p= 0.067
6MWT distance, m	rho = -0.011; p= 0.946

Definition of abbreviations: ADL: activity of daily living; BP: backpack; ESWT: Endurance shuttle walk test; min: minutes; rho: Spearman's correlation coefficient; 6MWT: six-minute walk test

Table 5. Characteristics of study participants who performed Glittre Endurance test before and after pulmonary rehabilitation (n=17).

Characteristic	Mean (SD)
Sex, M/F	14/3
Age, years	68 (7)
BMI, Kg/m^2	24 (6)
FEV_1, % predicted	49 (18)
FVC, % predicted	86 (247
FEV_1/FVC	0.46 (0.14)
SGRQ	
Total	47 (14)
Symptoms	55 (28)
Activity	61 (18)
Impact	37 (18)

Data presented as mean (SD). BMI: body mass index; FEV_1: forced expiratory volume in one second; FEV_1/FVC: ratio between forced expiratory volume in one second and forced vital capacity; FVC: forced vital capacity; kg/m^2: kilograms per metre squared; pred: predicted; SGRQ: St George's Respiratory Questionnaire

Table 6. Responsiveness for Glittre Endurance test after 8 weeks of pulmonary rehabilitation (n=17)

	Baseline	**Week 8**	**Difference within group**	**Cohen's d**
	Mean (SD)	**Mean (SD)**	**Mean difference (95%CI)**	
Glittre ADL test with BP, min	3.81 (0.88)	3.26 (0.61)	-0.56 (-0.90 to -0.21)*	0.83
Glittre ADL test without BP, min	3.60 (0.65)	3.19 (0.52)	-0.41 (-0.68 to -0.15)*	0.80
Glittre Endurance test, min	8.28 (4.17)	11.63 (6.03)	3.28 (1.51 to 5.04)*	0.98
ESWT, min	7.32 (4.31)	15.06 (6.38)	7.74 (4.74 to 10.75)*	1.33
6 MWT distance, meters	464 (77)	509 (85)	46 (19 to 72)*	0.87

Definition of abbreviations: ADL: activity of daily living; BP: backpack; ESWT: Endurance shuttle walk test; min: minutes; rho: Spearman's correlation coefficient; 6MWT: six-minute walk test

*significant difference $p<0.05$.

CHAPTER 7

DO GLITTRE-ADL TESTS REFLECT DAILY PHYSICAL ACTIVITY?

INTRODUCTION

With the progression of the disease, people with chronic obstructive pulmonary disease reduce their functional capacity, which is strongly correlated with morbidity and mortality in this population (Barnes & Celli, 2009). Functional capacity is a measure of the maximal capacity to achieve a functional activity in a standardised environment (Bui et al., 2017). One of the goals of pulmonary rehabilitation is to increase the functional capacity of people with COPD (Kocks et al, 2011). In this context, field tests were developed to assess functional capacity before and after pulmonary rehabilitation programs (Holland et al., 2014). These tests are considered representative of individuals' functional capacity and the choice of the most appropriate test depends on the information that is needed and the resources available.

Functional performance, alternatively, is a measure of what an individual actually does in daily life (Spruit et al., 2013) and should be evaluated in non-laboratory conditions to represent the level of activity that an individual does in everyday life. Evaluation of functional performance can be made by direct observation in individuals' real environment, by questionnaires or using technologies such as activity monitors (Bui et al., 2017).

Functional capacity measured by field tests is part of the assessment of individuals with COPD before and after pulmonary rehabilitation programs (Bui et al., 2017; Holland et al., 2014), while, functional performance might be more

relevant for clinical management because it reflects the patients' real levels of activity (Karloh et al., 2016).

The Glittre-ADL test has been considered the most comprehensive test to assess the functional capacity of patients with COPD (Bui et al., 2017). In chapter 4 it was demonstrated that the Glittre-ADL test performed without the backpack provoked the same physiological responses as the test with the backpack. In addition, Glittre Endurance test in chapter 6 was developed to assess endurance capacity for functional tasks that are important for daily life in people with COPD.

Accelerometers are devices that measure functional performance in terms of physical activity. Physical activity is defined as any movement produced that results in energy expenditure (Caspersen, Powell & Christenson, 1985). Previous studies have shown that the levels of physical activity in people with COPD are much lower than in the general population (Watz et al., 2014; Pitta et al., 2005). Karloh et al. (2016) have shown a moderate relationship between performance on Glittre-ADL test (as a measure of functional capacity) with physical activity levels (as a measure of functional performance) (Karloh et al., 2016). As the Glittre test performed without the backpack and Glittre Endurance test are potentially appropriate tests and also include tasks that are commonly performed in daily activities, it might be expected that there would be a good relationship between these tests and measurements of physical activity. Therefore, the aim of this study was to evaluate whether the Glittre-ADL tests performed with and without the backpack, and the Glittre Endurance test reflect daily physical activity levels assessed by an accelerometer.

METHODS

Participants and study design

This was a cross-sectional study. Participants were recruited from referrals to an outpatient pulmonary rehabilitation program at Royal Prince Alfred Hospital, Sydney, Australia. Participants were included in the study if they had a diagnosis of COPD (GOLD, 2019) and were stable over the past month. Exclusion criteria were: concomitant cardiovascular, orthopaedic or neurological conditions that were likely to impair exercise; other significant pulmonary disease; body mass index over 35kg/m^2; major psychiatric illness. Written informed consent was obtained from all participants. The trial was registered ANZCTR 12617000920392 and was approved by the Sydney Local Health District (RPAH zone) Ethics Committee (X14-0199 & HREC/14/RPAH/261**).**

Measures

Glittre-ADL test with and without a backpack

Test description and technical details about the tests have been shown in chapter 4.

Glittre Endurance test

Test description and technical details about the test have been shown in chapter 5.

Axivity AX3

Daily physical activity was measured with an activity monitor (Axivity AX3 Newcastle, United Kingdom) worn for seven days. The Axivity AX3 is a valid (Godfrey et al., 2014) and reliable (Moore et al., 2017) tri-axial accelerometer that measures the number of steps and the time spent in sedentary, light, moderate and vigorous activities by participants. As it is waterproof it does not need to be removed

for bathing. The device was placed at the middle of the anterior right thigh of participants and they were instructed to maintain their routine of daily activities while wearing the device. The variables considered for analysis were: total number of steps and time spent in light, moderate and vigorous activities.

Other measures

Spirometry was performed using a calibrated portable spirometer (Easy One spirometer; nnd Medical Technologies Inc., Andover, MA, USA) according to standard procedures (Miller et al., 2005). Obtained measures were compared to normative data (Gore et al., 1995) and disease severity was classified according to GOLD criteria (GOLD, 2019).

Health-related quality of life (HRQoL) was measured by the St George's Respiratory Questionnaire (SGRQ) which has 53 items and assess three domains: symptoms, activity limitations and impact of disease (Jones et al., 1992).

Procedures

Participants attended for three data collection sessions over a 14-day period. On the first visit, demographic data such as height, weight and age were recorded. The participants then executed spirometry, completed the SGRQ, and completed two Glittre-ADL tests with the backpack to eliminate the learning effect. On the second visit, participants completed one Glittre-ADL test with the backpack and one without the backpack, in random order. The order of the tests was randomized in blocks by a computer program (https://www.random.org/). The randomisation sequence was kept in sealed, opaque envelopes and only opened prior to the first test on the second visit. On the third visit, participants performed two Glittre Endurance tests. Participants rested for 30 minutes between each test or until all parameters had returned to baseline levels. The time to complete each Glittre-test was recorded as the test

outcomes. During all tests, oxygen saturation (SpO_2) and pulse rate were continuously monitored (Masimo Rad 5, Masimo Corporation or Novametric, Respironics for Australian participants and Nonin 8000R, Nonin Medical Inc, USA, for Brazilian participants).

Sample size

To achieve a significant result of $p<0.05$ with a power of 80% to detect a moderate correlation of 0.6 between the Glittre tests and measures of physical activity, a minimum sample size of 19 participants was required (Guenther, 1977).

Data analysis

Data are presented as mean and standard deviation, unless otherwise stated and the normality was verified by the Shapiro-Wilk test. Comparisons between number of steps and time spent in sedentary, light, moderate, and vigorous activities between week and weekend days were performed by paired *t*-tests or Wilcoxon tests, according to data normality. To determine the relationship between the Glittre tests and accelerometer data, the Pearson or Spearman correlation coefficient was used, according to data normality. The strength of the correlations was defined as < 0.20 as minimal or absent, from 0.25 to 0.50 as weak, from 0.50 to 0.75 as moderate, and from 0.75 to 1.0 as strong (Portney & Watkins, 2009). The level of significance was set at 5%. The Statistical Package for the Social Sciences (SPSS) v 15.0 (Chicago, IL, USA) was used for analyses.

RESULTS

Participant characteristics

Twenty-four participants were recruited and 18 completed the study. Two participants dropped out of the study, one declined to use the activity monitor, one

performed the field tests, but did not return to wear the activity monitor, two removed the monitors after five days of wear and so their data was not used. Table 1 presents demographic, anthropometric, spirometric, and clinical data of the participants. Two participants were classified as GOLD 1, 6 as GOLD 2, 7 as GOLD 3, and 3 as GOLD 4.

Number of steps and physical activity in daily life

Table 2 presents the data related to the accelerometer worn by participants for seven days. There were no significant differences in the number of steps per day during the week and the weekend. Participants spent 12% of the monitored time in light activities (1.5-3.99 metabolic equivalents [METS]), 10% in moderate activities (4.0-6.99 METS), and 0.5% in vigorous activities (≥7.0 METS).

Relationship between Glittre test times and activity monitor data

Correlations between Glittre test times and number of steps and time spent in each activity level are presented in table 3. There were moderate correlations of the Glittre tests with number of steps and light, moderate and vigorous levels of physical activity in daily life. Glittre-ADL and Glittre Endurance test times correlated moderately with number of steps over the week. Glittre-ADL test time also correlated with time spent in moderate activity, while Glittre Endurance test time correlated with time in vigorous activities.

DISCUSSION

The findings of this study demonstrated that: 1) Glittre-ADL test time correlated moderately with number of steps and time spent in moderate activities; 2) Glittre-ADL test time performed without the backpack was moderately correlated

with number of steps over the week; 3) Glittre Endurance test time was moderately correlated with total number of steps and time spent in vigorous activities.

These findings demonstrated that the Glittre test times had a moderate relationship with measures of real life such as number of total steps and time spent in moderate and vigorous activities. All Glittre tests correlated to number of steps over the week. Steps per day is one of the strongest predictors of mortality in people with COPD (Waschki et al, 2011) with 3006± 2081 steps per day being the cut-point for separating survivors from non-survivors. The number of steps per day observed in this study were similar to the number of steps per day (i.e. 4579) reported previously in a systematic review and meta-analyses of 2621 COPD participants (Saunders et al., 2016). Demeyer et al. (2016), recently reported that an increase of 600-1100 steps per day reduces the risk for hospital admissions in patients with COPD (Demeyer et al., 2016). Therefore, strategies to increase physical activity levels in people with COPD have been developed and pedometers have been considered useful tools to provide a feedback to patients about their daily activities aiming to improve steps per day (Mendonza et al., 2015). The authors also suggested that it may be more reasonable to try to reduce patients' time in sedentary activities by increasing their participation in light activities in daily life (Mendonza et al., 2015).

In the present study, the moderate correlation with the number of steps was observed for all Glittre tests. Thus Glittre tests may provide clinicians with an indication of level of daily physical activity of people with COPD without having to use an activity monitor. Such information could help clinicians plan strategies to increase physical activity level in people with COPD. However, larger studies are needed in COPD patients with a range of disease severity in order to confirm the relationships between the Glittre tests and daily physical activity.

Glittre tests had a moderate negative correlation with time spent in moderate and vigorous activities, i.e. the shorter the Glittre-ADL test the higher the level of moderate physical activity. In addition, there was a moderate positive correlation of the Glittre Endurance test with vigorous physical activity i.e. the longer the Glittre Endurance test the higher the level of vigorous physical activity. Therefore, both tests are good tools to reflect daily activities assessed by an accelerometer. Although the Glittre-ADL test performed without the backpack proved to be a similar tool to assess functional capacity in people with COPD compared with Glittre-ADL test, the test performed without the backpack did not reflect daily activities very well as no correlation was shown. Similar to our results, Karloh and colleagues (2016) showed that Glittre-ADL test time significantly correlated with number of steps taken (r=-0.53) and walking movement intensity (r=-0.66) as well as time walking (r=-0.46), and total energy expenditure (r=-0.33). Participants, however, only wore the monitor for two days (Karloh et al, 2016) which may not have been adequate to reflect overall daily activities.

To our knowledge, this is the first study to demonstrate whether the Glittre-ADL test performed without the backpack and the Glittre Endurance test are representative of daily activities. The findings of this study enhance the usefulness of the Glittre tests as tools to not only to assess functional capacity of people with COPD, but also to reflect their daily activities.

CONCLUSION

In conclusion, the Glittre-ADL test, Glittre-ADL test performed without the backpack, and the Glittre Endurance test all demonstrated an ability to reflect daily activities assessed by an accelerometer. Although all Glittre tests correlated with the

number of steps per day, only Glittre-ADL test and Glittre Endurance test correlated with the time spent in different activities levels. Therefore, Glittre-ADL test and Glittre Endurance test have demonstrated to be superior to Glittre-ADL test performed without the backpack to reflect daily activities.

Table 1. Characteristics of study participants (n=18).

Characteristic	Mean (SD)
Sex, M/F	9/9
Age, years	70 (7)
BMI, Kg/m^2	23 (4)
FEV_1, % predicted	53 (22)
FVC, % predicted	92 (27)
FEV_1/FVC	0.47 (0.14)
SGRQ	
Total	45 (17)
Symptoms	51 (24)
Activity	64 (22)
Impact	32 (19)

Data presented as mean (SD). BMI: body mass index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; FEV_1/FVC: ratio between forced expiratory volume in one second and forced vital capacity; kg/m^2: kilograms per metre squared; pred: predicted; SGRQ: St George's Respiratory Questionnaire

Table 2. Accelerometer data during seven days and time to perform each Glittre test.

	Total Mean (SD)	**Week days Mean (SD)**	**Weekend days Mean (SD)**	**p value**
Number of steps	31543 (22113)	4607 (3400)	4253 (2776)	0.306
Time in light activities, minutes	1211 (385)	171 (56)	176 (58)	0.543
Time in moderate activities, minutes	1010 (527)	143 (74)	147 (82)	0.566
Time in vigorous activities, minutes	53 (100)	8 (14)	7 (17)	0.213
Glittre Tests results				
Glittre-ADL test time, minutes	4.28 (1.77)			
Glittre-ADL test without the BP time, minutes	4.26 (1.72)			
Glittre Endurance test time, minutes	8.40 (2.87)			

Definition of abbreviations: ADL: activities of daily living; BP: backpack; number of steps and time in each activity level on week and weekend days are presented in amount per day; p-value relates to week days vs weekend days

Table 3. Relationship between Glittre-ADL tests and accelerometer data during the seven days.

Glittre-ADL test	**Glittre-ADL test time**	**Glittre-ADL test without BP time**	**Glittre Endurance Test time**
Number of steps over the week	rho = -0.554; p= 0.017*	rho = -0.501; p= 0.034*	rho = 0.687; p= 0.003*
Time in light activities, minutes	rho = -0.363; p= 0.139	rho = -0.308; p= 0.214	rho = 0.468; p= 0.067
Time in moderate activities, minutes	rho = -0.485; p= 0.042*	rho = -0.436; p= 0.071	rho = 0.403; p= 0.122
Time in vigorous activities, minutes	rho = -0.447; p= 0.063	rho = -0.428; p= 0.076	rho = 0.561; p= 0.024*

Definition of abbreviations: ADL: activities of daily living; BP: backpack; rho: Spearman correlation coefficient; * significant correlation

CHAPTER 8

CONCLUSION

MAIN FINDINGS

Chronic pulmonary disabilities encompasses any impairment in body function or structure, any limitation in activity, and any restriction in participation as a result of a lung condition. Therefore, comprehensive information about functioning and disabilities obtained by the initial assessment is crucial to guide clinicians to design appropriate rehabilitation interventions. To perform a good assessment, appropriate evaluation tools should be available to observe impairments, detect activity limitations and identify participation restrictions. Taking this into consideration, this thesis aimed to present new approaches to improve the assessment of people with chronic pulmonary disabilities.

Breathing pattern data provides important information about respiratory movement, and is part of physiotherapy assessment of individuals with acute and chronic pulmonary disorders (Verschakelen & Demedts, 1995; Britto et al., 2005; Tobin, 1992). Optoelectronic plethysmography emerged as a valid and reliable method capable of evaluating breathing pattern with important advantages (Cala et al., 1996; Vogiatzis et al., 2005; Vieira et al., 2013). Several studies have used OEP in the assessment of different health conditions (Parreira et al., 2012). However, up to now, reference values for the variables evaluated by this method have not been established. The study in Chapter 3 is the first to develop reference values for breathing pattern assessment using optoelectronic plesthysmography. The reference values were established for all variables analysed by this method for 168 healthy

individuals age ranges from 21 to 91 years in three different positions: seated, supine, and supine with trunk inclination of 45°. The study had a multicenter design, and therefore, had a sample composed by individuals from different regions of Brazil.

Functional capacity evaluation is another important area of physiotherapy assessment of individuals with chronic pulmonary disabilities as it shows the maximal capacity of an individual to achieve a functional activity (Bui et al, 2017). Non-laboratory-based field tests are considered representative of individuals' functional status (Holland et al., 2014; Bui et al., 2017) and can be used to assess functional capacity before and after pulmonary rehabilitation programs. The Glittre-ADL test has been considered a useful test to evaluate individuals with COPD as it involves multiple functional activities (Skumlien et al., 2006; Bui et al., 2017), is reliable, and presents good responsiveness to pulmonary rehabilitation (Skumlien et al., 2006; Bui et al., 2017). The study in Chapter 4 assessed the differences in performing Glittre-ADL test with and without the backpack in participants with COPD. The findings demonstrated in 40 participants from mild to very severe disease that there were no differences in physiological response (HR and SpO_2) or symptoms (dyspnoea and RPE) for the test performed without the backpack compared to with the backpack, except for upper limb fatigue that was reported by males as significantly higher for the test performed with the backpack. These results support the use of Glittre-ADL test performed without the backpack and such a test might be a safer, especially for patients with problems of balance and coordination.

Further modifications of the Glittre-ADL test are presented in Chapter 5. The outcome for the Glittre-ADL test is the time taken to complete five laps of the test, however previous studies have observed that oxygen consumption reached a plateau after the third lap (Karloh et al., 2014; Tuffanin et al., 2014). These findings suggest

that the Glittre-ADL test might be adequately performed in three laps instead of five laps. The study in Chapter 5 aimed to compare the differences in performance of the Glittre-ADL test with and without the backpack in three and five laps in 41 COPD participants with mild to very severe disease. The three-lap test provoked the same symptoms and oxygen desaturation to the Glittre-ADL test performed in five laps. The heart rate was significantly lower for both Glittre-ADL tests performed in three laps, however, the difference was small (three beats per minute) and unlikely to be of clinical relevance. These findings meant that 3-lap Glittre-ADL test might be a more practical alternative to the 5-lap test. However, the Glittre-ADL test performed in three laps demonstrated a learning effect even when it was performed for the third time in participants with more severe COPD. Therefore, for more severe patients, the test should be performed three times.

Endurance capacity measured by the ESWT is a more sensitive measure of change in functional capacity after pulmonary rehabilitation (Eaton et al., 2006; Revill et al., 1999). However, the ESWT only measures walking endurance. A new test of endurance capacity for functional activities, the Glittre Endurance test, was developed and evaluated in chapter 6. Fifty-two participants with COPD were recruited to develop and evaluate the Glittre Endurance test. In 43 participants Glittre Endurance test was demonstrated to be an appropriate test to assess endurance capacity and a sensitive measure of change in functional capacity of patients with COPD after pulmonary rehabilitation.

This thesis also investigated the relationship between the Glittre tests and physical activity in Chapter 7. Physical activity was measured using the Axivity monitor which is a relatively new device which is waterproof, thus allowing the assessment of people with COPD for the whole time and reduces the loss of data due

to participants forgetting to reapply a monitor after bathing. In the 18 participants with COPD evaluated, all the functional Glittre tests demonstrated good ability to reflect daily activities.

CLINICAL IMPLICATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The reference values established in Chapter 3 will contribute to the assessment in body functions and structure and later can be important for comparison and better understanding of the alterations in individuals with different respiratory impairments that may compromise respiratory function. The reference values were established for all variables evaluated by optoelectronic plethysmography for there different positions: seated, supine and supine with 45° of trunk inclination. Initially the proposal was develop reference values for each ten-year increment in age for individuals aged from 20 to 80 and above years. However, the lower number of participants in 70 to 79 and 80 to 89 age ranges did not allow the development of values for these ranges. Therefore, participants from 60 to above were grouped. Further development of reference values for these decades separately can be important for more accurate comparisons.

Another important aspect to be evaluated in individuals with chronic pulmonary disabilities is functional capacity. The choice of the most appropriate test depends on the information that is needed and the resources available. Simple, practical and functional tests representative of individuals' functional status (Holland et al., 2014; Bui et al., 2017) are preferred by clinicians and should be used to assess functional capacity before and after pulmonary rehabilitation programs. Aiming contributing for improvements in functional tests, Chapters 4 and 5 proposed modifications in Glittre-ADL test that has been considered a useful test to evaluate

individuals with COPD as it involves multiple functional activities (Skumlien et al., 2006; Bui et al., 2017). Chapter 4, proposed a potentially safer test that was reported by participants as more tolerable while remained a good test of functional capacity for activities of daily living. The backpack removal may allow the assessment of COPD patients with deficits in balance and coordination that initially could not be eligible for test performance with the backpack for safety purposes. This modification also helps clinicians as it makes the test more practical and less material is needed. Further studies using direct measures of metabolic and ventilatory responses during the test should be conducted to confirming and understanding the metabolic and ventilatory differences involved in Glittre-ADL tests with and without the backpack performance as well as to investigate weather the test is more safety.

To help clinicians with more practical tests, Chapter 5 proposed the performance of both the original test performed with the backpack and the test performed without the backpack in three laps instead of five laps. The findings suggested that the 3-lap test could be an alternative to the 5-lap test, which would reduce overall testing time and thus be a more acceptable test for busy clinicians. Further studies to confirm the learning effect in the 3-lap test should be conducted to confirm whether the learning effect is evident on a third test when participants are naive to the Glittre-ADL test, especially for the test performed without the backpack.

To expand the possibilities of available tests to assess functional capacity, a new test of endurance capacity for functional activities, the Glittre Endurance test, was developed and evaluated in Chapter 6. This test can help clinicians to better show pulmonary rehabilitation effects as endurance capacity has been shown a more sensitive measure of change (Eaton et al., 2006; Revill et al., 1999). The Glittre Endurance test was shown to be highly responsive to pulmonary rehabilitation, even

the sample size was not enough powered. Further studies, however, aiming evaluating whether there was a learning effect for the Glittre Endurance test should be performed.

As previously showed, functional capacity measured by field tests is part of the assessment of individuals with COPD before and after pulmonary rehabilitation programs (Bui et al., 2017; Holland et al., 2014), however the assessment occurs in standard environmental that not always reproduces patients' real life. In this context, functional performance might be more relevant for clinical management because it reflects the patients' real levels of activity as it is measured in their real lives. Its assessment however is dependent of more complex instruments such as accelerometers, the clinicians' involvement in patients' home or of the use of questionnaires that may be subject to memory bias (Karloh et al., 2016). Chapter 7 contributed therefore to demonstrate whether the Glittre-ADL test performed without the backpack and the Glittre Endurance test are representative of daily activities. The findings of this study enhance the usefulness of the Glittre tests as tools to not only to assess functional capacity of people with COPD, but also to reflect their daily activities.

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ANNEX

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM PESQUISA - COEP

Parecer nº. ETIC 0194.0.203.000-11

Interessado(a): Profa. Verônica Franco Parreira
Departamento de Fisioterapia
EEFFTO - UFMG

DECISÃO

O Comitê de Ética em Pesquisa da UFMG – COEP aprovou, no dia 15 de junho de 2011, o projeto de pesquisa intitulado **"Avaliação do padrão respiratório e do movimento toracoabdominal no repouso e durante a realização de exercícios respiratórios em indivíduos saudáveis"** bem como o Termo de Consentimento Livre e Esclarecido.

O relatório final ou parcial deverá ser encaminhado ao COEP um ano após o início do projeto.

Profa. Maria Teresa Marques Amaral
Coordenadora do COEP-UFMG

Av. Pres. Antonio Carlos, 6627 – Unidade Administrativa II - 2º andar – Sala 2005 – Cep: 31270-901 – BH-MG
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Health
Sydney
Local Health District

19 April 2017

Professor Jennifer Alison
Discipline of Physiotherapy
Room 166, O Block
Faculty of Health Sciences
PO Box 170
LIDCOMBE NSW 1825

Dear Professor Alison,

Re: Protocol No X14-0199 - "Evaluating functional capacity and a simple method of enhancing exercise training intensity in people with chronic obstructive pulmonary disease (COPD)"

HREC/14/RPAH/261 **SSA/14/RPAH/262**

I refer to your correspondence of 19 April 2017. Following submission of the required documentation, authorisation is given for the addition of the following as an associate investigator on the above project:

- Ms Liliane MENDES

Yours sincerely,

Maree Larkin
Research Governance Officer
SLHD (RPAH Zone)

RGO - Maree\CORRES\X14-0199

UNIVERSIDADE FEDERAL DE MINAS GERAIS

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: NOVO MÉTODO PARA AVALIAR A CAPACIDADE FUNCIONAL EM PACIENTES COM DOENÇA PULMONAR OBSTRUTIVA CRÔNICA

Pesquisador: Marcelo Velloso

Área Temática:

Versão: 1

CAAE: 02288818.0.0000.5149

Instituição Proponente: Escola de Educação Fisica da Universidade Federal de Minas Gerais

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.034.213

Apresentação do Projeto:

A doença pulmonar obstrutiva crônica (DPOC) é uma enfermidade respiratória que se caracteriza pela presença de obstrução crônica do fluxo aéreo, que não é totalmente reversível. A obstrução ao fluxo aéreo é geralmente progressiva e está relacionada a uma resposta inflamatória dos pulmões anormal em resposta à inalação de partículas ou gases tóxicos, sendo causada principalmente pelo tabaco(1).O processo inflamatório pode produzir alterações nos brônquios (bronquite crônica) e no parênquima pulmonar (enfisema pulmonar). A predominância dessas alterações é variável, sendo utilizado o termo DPOC para englobar ambas as doenças(1). A DPOC é um problema de saúde mundial, sendo a terceira maior causa de morte das doenças crônicas não transmissíveis no Brasil(2) e a terceira maior causa de morte no mundo(3).Com a progressão da doença, indivíduos com DPOC reduzem a capacidade de exercício. A baixa capacidade funcional está fortemente correlacionada com o aumento da morbidade e da mortalidade nesses indivíduos(4). Neste sentido, a reabilitação pulmonar surge como uma forma de tratamento, tendo como um dos objetivos, aumentar a capacidade funcional de indivíduos com DPOC(5), normalmente mensurada por meio do teste de caminhada dos seis minutos (TC6')(6). Embora o TC6' seja um teste largamente utilizado, ele não inclui a avaliação das atividades dos membros superiores (MMSS) que são muito importantes para a realização das tarefas funcionais diárias. Mais recentemente, o Glittre ADL Test foi desenvolvido e proposto como um teste que avalia melhor as atividades funcionais, pois inclui atividades de membros inferiores (MMII) e de MMSS, tais como,

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levantar da cadeira, andar, subir e descer escadas e uma tarefa que simula o manejo de objetos em um armário. Apesar de o Glittre ADL Test ter se correlacionado bem com o TC6'(7), não se sabe o quanto esse teste realmente reflete as atividades requeridas na vida diária. Além disso, a variável desfecho do Glittre ADL Test é o tempo gasto para completar cinco voltas na pista. Embora isso possa ser uma medida útil, normalmente as pessoas com DPOC após um programa de reabilitação pulmonar, não conseguem melhorar significativamente a velocidade com que desempenham suas atividades, mas podem ser capazes de realiza -las por mais tempo e com menos sintomas, como fadiga e falta de ar. Por esse motivo, torna-se interessante investigar se uma modificação no Glittre ADL Test pode refletir melhor a capacidade de resistência para a realização de tarefas funcionais, e, ainda, determinar como essa medida se relaciona com os niveis de atividades diárias medidos objetivamente por meio de um monitor por sete dias. Essa ideia tem respaldo na literatura, tendo em vista que recentemente foi demonstrado que a capacidade de resistência, medida pelo Endurance Shuttle Walk Test (ESWT), para os MMII, é uma medida mais sensivel da mudança da capacidade de exercício após a reabilitação pulmonar quando comparado ao TC6'(8). Além disso, no Glittre ADL Test os individuos do sexo feminino carregam uma mochila de 2,5 kg e os individuos do sexo masculino 5,0 kg, para simular o peso de um equipamento suplementar de oxigênio. No entanto, na prática clínica não é comum vermos pacientes carregando oxigênio em mochilas. Dessa forma, torna-se interessante investigar a influência da retirada da mochila para realização do teste.

Metodologia Proposta: Será realizado um estudo quasi experimental. O estudo será realizado no Laboratório de Avaliação e Pesquisa em Desempenho Cardiorrespiratório da Universidade Federal de Minas Gerais. Serão avaliados individuos com DPOC leve (GOLD I), moderada (GOLD II), grave (GOLD III) ou muito grave (GOLD IV)3 que tenham sido encaminhados para realização da espirometria ou para reabilitação pulmonar. Também serão avaliados individuos que tenham imediatamente finalizado a reabilitação pulmonar ou que a tenham realizado previamente e que atendam aos critérios de inclusão.Inicialmente, os indivíduos receberão informações sobre a pesquisa e após a prova de função pulmonar realizarão dois TC6'. Em seguida, os sujeitos responderão ao questionário do Hospital Saint George e realizarão dois testes de argola dos seis minutos. Os individuos irão descansar por pelo menos meia hora entre os testes ou até os valores de frequência cardíaca (FC), a saturação periférica de oxigênio (SpO2), sintomas de dispneia e fadiga retornarem aos valores de repouso. No segundo dia, os individuos serão convidados a voltarem após intervalo mínimo de um dia para realização de dois testes Glittre ADL, um Glittre ADL sem a mochila e um Endurance Shuttle Walk Test (ESWT). O Glittre ADL test realizado sem a

mochila será utilizado como referência para o Endurance Glittre test. No terceiro dia, os individuos serão convidados a retornar para realização de dois testes Glittre Endurance e um segundo ESWT. Durante cada teste o gasto energético será medido por meio do monitor de atividade, e, em um subgrupo de participantes, o consumo de oxigênio será medido por meio do sistema do analisador de gases portátil. No último dia de coleta de dados, os individuos serão solicitados a realizarem o teste de preensão manual, dois testes Unsupported upper limb exercise e o five-repetition sit to stand. Entre o primeiro e segundo dia, segundo e terceiro ou terceiro e quarto dias de coleta de dados os individuos serão equipados com o monitor de atividade para ser utilizado durante sete dias.
Hipótese: - O Glittre Endurance Test vai se relacionar significativamente com o ESWT;- O Glittre Endurance Test vai se correlacionar mais fortemente com o nivel de atividade fisica do que o ESWT e TC6'.

Objetivo da Pesquisa:
Objetivo Primário: • Avaliar a relação do Glittre Endurance Test com testes já existentes para avaliação da capacidade funcional, como o TC6', ESWT, Glittre ADL Test, teste de argola dos seis minutos, Unsupported upper limb exercise test e five-repetition sit to stand em individuos com DPOC.
Objetivo Secundário: • Avaliar a responsividade do Glittre Endurance Test (modificação do Glittre ADL Test) como medida de resultado dos efeitos da reabilitação pulmonar em uma amostra de individuos com DPOC;• Avaliar o impacto da retirada da mochila no desempenho do Glittre ADL Test;• Determinar a relação entre o Glittre Endurance Test e o nivel de atividade fisica, medido por um monitor, em individuos com DPOC;• Determinar a relação entre o Glittre Endurance Test e a pressão manual medida por meio de dinamômetro, em individuos com DPOC.

Avaliação dos Riscos e Beneficios:
Segundo os autores:
Riscos: Os participantes poderão sentir dores musculares nas pernas e nos braços durante e após a realização dos testes, pois ambos os testes exigem esforço fisico maior do que aquele que eles provavelmente estão acostumados. Essas dores podem durar por até cinco dias, entretanto essas dores são passageiras e não os impedirão de seguir com suas atividades do dia a dia. Os participantes também podem sentir cansaço e aumento dos batimentos cardiacos. Essas alterações são normais durante qualquer esforço e serão monitoradas durante os testes por instrumentos

confiáveis. Os participantes também poderão sentir um leve desconforto devido à utilização da máscara facial durante a realização de alguns testes. Se for percebido qualquer sintoma diferente do habitual, o procedimento será imediatamente interrompido.
Benefícios: Os resultados encontrados com o estudo contribuirão para melhorar a avaliação da capacidade de exercício de pacientes com doença pulmonar obstrutiva crônica utilizando o Glittre Endurance Test. Ao se verificar a precisão das medidas fornecidas por um novo teste, ele se torna acessível para ser utilizado na prática clínica e em pesquisas. Além disso, os participantes receberão uma avaliação do sistema respiratório (espirometria).

Comentários e Considerações sobre a Pesquisa:
Trata-se de um estudo não multicêntrico, quasi experimental. O estudo será realizado no Laboratório de Avaliação e Pesquisa em Desempenho Cardiorrespiratório da Universidade Federal de Minas Gerais. Serão avaliados indivíduos com DPOC leve (GOLD I), moderada (GOLD II), grave (GOLD III) ou muito grave (GOLD IV)3 que tenham sido encaminhados para realização da espirometria ou para reabilitação pulmonar. Também serão avaliados indivíduos que tenham imediatamente finalizado a reabilitação pulmonar ou que a tenham realizado previamente e que atendam aos critérios de inclusão. Pesquisa relevante para área de Ciências da Saúde, com propósito clínico. Texto bem fundamentado e bem delineado. Projeto com início em novembro de 2018 e previsão de término em julho de 2022.

Considerações sobre os Termos de apresentação obrigatória:
Foram apresentados os seguintes documentos:
Informações básicas do projeto;
Projeto detalhado;
Folha de rosto;
Parecer consubstanciado emitido pela chefia do Departamento Fisioterapia da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da UFMG;
TCLE.

Recomendações:
- No TCLE, conforme Res. 466/12:
- Iniciar o documento em forma de carta convite. Portanto, a equipe de pesquisadores deve ser inserida no corpo do texto;

- Inserir numeração de páginas;
- Inserir a informação;
- O TCLE deverá conter, obrigatoriamente a garantia de que o participante da pesquisa receberá uma via do Termo de Consentimento Livre e Esclarecido. Portanto a informação "Caso o senhor (a) queira solicitar uma via assinada pelo pesquisador, você poderá entrar..." deverá ser substituida por outra que informe que o TCLE será assinado em duas vias e uma delas ficará em posse do participante da pesquisa.

Conclusões ou Pendências e Lista de Inadequações:

Projeto aprovado, no entanto, o pesquisador deverá atender as recomendações solicitadas.

Considerações Finais a critério do CEP:

Tendo em vista a legislação vigente (Resolução CNS 466/12), o CEP-UFMG recomenda aos Pesquisadores: comunicar toda e qualquer alteração do projeto e do termo de consentimento via emenda na Plataforma Brasil, informar imediatamente qualquer evento adverso ocorrido durante o desenvolvimento da pesquisa (via documental encaminhada em papel), apresentar na forma de notificação relatórios parciais do andamento do mesmo a cada 06 (seis) meses e ao término da pesquisa encaminhar a este Comitê um sumário dos resultados do projeto (relatório final).

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_853657.pdf	05/11/2018 10:15:45		Aceito
Declaração de Instituição e Infraestrutura	Anuencia.pdf	24/10/2018 21:32:41	Liliane Mendes	Aceito
Declaração de Instituição e Infraestrutura	Aprovacao_camara_Glittre_Endurance.PDF	23/10/2018 16:02:34	Liliane Mendes	Aceito
Folha de Rosto	Folha_de_rosto_Glittre_Endurance.PDF	23/10/2018 16:01:50	Liliane Mendes	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_Projeto_Glittre_Endurance.pdf	18/10/2018 09:40:21	Liliane Mendes	Aceito
Projeto Detalhado / Brochura	Projeto_Glittre_Endurance.pdf	18/10/2018 09:39:52	Liliane Mendes	Aceito

Endereço: Av. Presidente Antônio Carlos,6627 2º Ad SI 2005
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Investigador	Projeto_Glittre_Endurance.pdf	18/10/2018 09:39:52	Liliane Mendes	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

BELO HORIZONTE, 22 de Novembro de 2018

Assinado por:
Eliane Cristina de Freitas Rocha
(Coordenador(a))

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