CHANGING PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR IN PEOPLE WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE

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Abstract

People with chronic obstructive pulmonary disease (COPD) engage in low levels of physical activity (PA). Given the evidence for the health benefits associated with participating in 150 minutes of moderate-to-vigorous intensity PA each week, there is considerable interest in methods to increase PA in people with COPD. Studies to date have focused largely on exercise training and behavioural approaches and many have demonstrated minimal, if any effect. An intermediate goal, which focuses on reducing time spent in sedentary behaviour (SB) and increasing participation in light intensity PA is a more realistic goal in this population and offers a gateway to higher intensity PA. Although strategies that are capable of reducing time spent in SB in COPD are unknown, studies which have shown some increase in PA in this population often provide individualised goal setting, motivational interviewing and frequent contact with healthcare professionals to provide advice regarding strategies to overcome barriers. Therefore, these approaches should be considered in interventions to reduce time in SB. There are a range of devices available to monitor time in SB for use in both clinical and research settings. To move this area forward, a theoretically-informed and systematic approach to behaviour change is needed. The theoretical model, the 'behaviour change wheel', is described and an example is provided of how it can be applied to a person with COPD.

Keywords: Pulmonary Disease, Chronic Obstructive; motor activity; sedentary lifestyle; energy metabolism; health.

1 Introduction

For more than a decade, there has been interest in strategies to increase participation in physical activity (PA) in people with chronic obstructive pulmonary disease (COPD).[1] Despite the large number of studies that have explored the effect of interventions such as exercise training and behaviour change approaches, there is limited evidence that either can increase PA in this population.[1, 2] An alternative approach of reducing time in sedentary behaviour (SB) and increasing participation in light intensity PA is an appropriate and realistic intermediate goal for people with COPD, as well as a gateway to more intense activity.[3] Targeting a reduction in the time spent in SB may produce health benefits, even if increases in moderate-to-vigorous intensity PA (MVPA) are not realised.[4-6] This paper provides an overview of these concepts and concludes with the description of a theory-informed and systematic approach to behaviour change. The online supplement (Table S1) summarises the search terms used to find the papers described in this narrative review.

2 Review

2.1 Defining physical activity and sedentary behaviour

Physical activity is defined as any bodily movement generated by skeletal muscle that results in energy expenditure.[7] There is a spectrum of energy expenditure associated with different types of PA and activities are commonly classified as light, moderate or vigorous intensity[7, 8] (Figure 1). Activities or behaviours (other than sleep) that require low energy expenditure (≤ 1.5 METs) and are undertaken in sitting or a reclined posture, are classified as SB.[9] Examples of SB include reading and watching television.

2.2 What do we know about physical activity and sedentary behaviour in people with chronic obstructive pulmonary disease?

Earlier work has demonstrated that, compared with healthy controls, people with chronic obstructive pulmonary disease (COPD) spend around half the amount of time in waking hours participating in PA and 1.4 times more of their waking hours in SB.[10, 11] There are many factors that potentially influence PA and SB in people with COPD. Factors associated with lower levels of PA include greater airflow obstruction and static hyperinflation, greater dyspnoea on exertion, lower exercise capacity, greater impairment in peripheral muscle force, higher number of exacerbations in the past year, the need for long-term oxygen therapy, lower motivation to exercise and greater feelings of depression.[12] Factors associated with increased SB include lower exercise capacity, lower motivation to exercise, a higher number of exacerbations in the past year and the need for long-term oxygen therapy.[12] Of note, exacerbations, especially those that require hospitalisation, have a prolonged impact on PA and SB levels. When compared to people with stable COPD, those who have been hospitalised due to an acute exacerbation spend more time sitting and less time walking and standing, for up to one month after hospital discharge.[13]

2.3 Why is increasing physical activity a worthwhile goal in people with COPD?

There is a large body of evidence supporting the health benefits of participating in PA for the general population, particularly MVPA.[7, 14, 15] Health benefits associated with participating in ≥ 150 minutes per week of MVPA include reductions in cardiovascular and metabolic disease, risk of developing some cancers and all-cause mortality.[7, 14, 15] Closer to 300 minutes of MVPA is required for prevention of weight gain and obesity.[14, 15] Although aerobic activity, which is characterised by regular, continuous, rhythmic and purposeful movement of major muscle groups, is the cornerstone of these PA recommendations,[7] there is no clear evidence that one type of activity (e.g. walking) is more effective than another (e.g. cycling) in producing health benefits. The physiological adaptations associated with participation in regular MVPA that have been proposed to underpin these health benefits are diverse. For example, the risk reduction for cardiovascular events is most likely related to improvements in endothelial function,[16] whereas the risk reduction for developing certain cancers may relate to changes in hormones, reductions in systemic inflammation and adiposity and/or improvements in immune function.[17] The magnitude of these health benefits is thought to be greater in those who engage in regular, prolonged periods of sustained MVPA. This contention is supported by international organisations who recommend that adults participate in ≥ 30 minutes of MVPA on ≥ five days each week, accrued in bouts ≥ 10 minutes.[7, 14]

The reduction in all-cause mortality attributable to greater participation in PA that has been demonstrated in the general population is also applicable to people with COPD.[18-20] As well as the reduction in mortality risk, an increase in walking time equivalent to two or more hours each week has been associated with a 28% reduction in the risk of hospitalisation in this population.[20]

2.4 Strategies to change physical activity in people with COPD

In people with COPD, several studies have explored interventions that aim to optimise participation in daily PA.[1] These interventions can be broadly grouped as those that have used exercise training and/or behavioural approaches, such as goal setting and counselling. Offering a program of exercise training coupled with a behavioural change approach appears to be the optimal method to increase PA in people with COPD.

Although there is limited evidence that exercise training alone increases participation in PA,[1, 2] exercise training programs represent an ideal opportunity to initiate changes in health behaviours. This is because supervised exercise training programs allow people with COPD to interact regularly with healthcare professionals and ameliorate disease-specific barriers to increasing PA, such as dyspnoea on exertion.[21] Behaviour change approaches should include individual goal setting, collection of objective physical activity data on which to base goals and provide feedback, motivational interviewing, frequent contact with a healthcare professional to increase motivation, overcome barriers and encourage adherence.[22-27] Although data suggest that these approaches will optimise the likelihood of change, to date, there is little evidence that meaningful and sustained changes in PA, especially MVPA are achievable in people with COPD.

2.5 Why is changing physical activity so difficult in people with COPD?

Despite more than three decades of public health campaigns to increase PA, measures of PA obtained via self-report or pedometers show little, if any improvement, in the general population.[28] Changing PA in people with COPD is likely to be even more difficult as this population not only face the same barriers to PA as the general population, but also disease-specific barriers, such as dyspnoea during daily activities and the use of oxygen therapy.[12, 29] The difficulty associated with changing time spent in MVPA in people with COPD is likely to reflect, at least in part, the limited exercise capacity of these individuals, together with application of the same arbitrary cut-points developed for use in the general population to classify the intensity of PA. Specifically, the pulmonary and systemic consequences of COPD serve to limit aerobic capacity.[29] Earlier work has demonstrated that people with moderate COPD (FEV_1 = 50 ± 16%) have a peak aerobic capacity equivalent to 5.0 ± 1.0 METs (peak rate of oxygen uptake [VO_{2peak}] = 17.4 ± 3.8 ml·kg^{-1}·min^{-1}).[30] Peak aerobic capacity will be less in people with more severe disease. Therefore, as this population is unable to engage in activities that require energy expenditure greater than their peak aerobic capacity, many are simply incapable of engaging in any activity classified as vigorous intensity (i.e. ≥ 6.0 METs). In fact, their capacity to participate in moderate intensity activity is grossly limited, as moderate intensity PA (defined as activity requiring ≥ 3.0 METs) would demand a minimum of 60% of their capacity in those with moderate disease and a peak aerobic capacity of 5.0 METs. This is considerably more than individuals with a normal aerobic capacity (i.e. closer to 10.0 METs), in whom the requirements associated with moderate intensity PA are closer to 30% of their peak capacity. This has led to the development of cut-points to define MVPA that are relative to an individuals' peak aerobic capacity (Table 1).[7, 31]

Although using relative cut-points for defining MVPA in people with COPD allows them the opportunity to accumulate time in this domain, there are some concerns with this approach. First, it compromises the capacity to compare PA data with studies that have used the absolute cut-points. For example, in a previous study of people with moderate to severe COPD, compared with an absolute cut-point (i.e. ≥ 3.0 METs), the application of a relative cut-point to classify MVPA (i.e. 50% of VO_{2peak} reserve) doubled the amount of time people spent in this domain, (median [interquartile range] 49 [26 to 99] vs. 122 [51 to 202] min/day).[32] Second, and of greater concern, the use of relative cut-points may be less accurate in conveying the potential for some health benefits associated with MVPA, such as the reduction in risk of cardiovascular events. This is because, the change in endothelial function, a key mechanism proposed to underpin this risk reduction,[16] may be dependent on the absolute intensity of PA. Specifically, exercise undertaken at low absolute intensities (~ 2.5 METs for someone with a peak aerobic capacity of 10.0 METs) has been shown to have no effect on endothelial function.[33] Thus, measuring time spent in MVPA, defined using a cut-point that is relative to an individual's peak aerobic capacity and equivalent to < 3.0 METs, may not capture time spent in PA that is capable of reducing cardiovascular risk, by improving endothelial function. As both absolute and relative cut-points have strengths and weaknesses, future studies of people with COPD should consider reporting time spent in MVPA defined using both cut-points.

Given these challenges associated with accumulating ≥ 150 minutes of MVPA each week, defined using the cut-point of ≥ 3.0 METs, an intermediate goal which focuses on reducing time spent in SB and increasing light intensity PA is appropriate. Targeting a reduction in time spent in SB and an increase in light intensity PA may also yield health benefits, even if increases in MVPA are not realised.[34, 35]

2.6 Why is reducing sedentary behaviour a worthwhile goal in people with COPD?

Even amongst those who participate in the recommended 150 minutes of MVPA each week, the percentage of total waking hours spent engaging in MVPA is low, with the majority of time spent in SB or light intensity PA.[3] This has led to a recent interest in exploring how the activities and behaviours that we spend most of our day engaging in, may impact on health outcomes. In the general adult population, greater time in SB has been associated with an increased risk for all-cause mortality.[4, 6, 36] As time in SB is almost perfectly inversely related to time spent in light intensity PA,[35] it seems likely that any reduction in SB will result in an increase in light intensity PA, which has been associated with health benefits.[37] Of note, the relationship between greater time in SB and risk for all-cause mortality appears at least partly independent of the amount of time a person participates in MVPA.[4] This suggests that participation in MVPA may not be able to fully counteract the deleterious effects of spending extended periods in SB. It also suggests that the mechanisms underpinning the health benefits of increasing MVPA may be different to those associated with reducing SB. Just as for PA, the way in which time spent in SB is accumulated seems to be important with those who accumulate time in SB in prolonged uninterrupted bouts at increased risk of developing cardiovascular and metabolic diseases.[38, 39] Although evidence is lacking regarding how often, and for how long, periods of SB should be interrupted, studies are emerging that aim to interrupt time in SB with light PA every 30 minutes (i.e. Stand Up For Your Health)[40, 41] and recommendations about reducing SB and breaking up periods of sitting now appear in guidelines for Australians.[42]

In line with the growing interest in the health consequences of SB, data are emerging on the impact SB has on health outcomes in people with COPD. Although one study of people with COPD found no differences in objectively measured time spent in SB between those with and those without metabolic syndrome, SB was associated with greater waist circumference and fasting blood glucose levels, suggesting greater cardio-metabolic risk.[43] An increase in SB occurs both during hospitalisation and at one month following hospitalisation for an acute exacerbation,[13] and this may represent a risk factor for subsequent hospitalisation. The consequences of SB in people with COPD on health outcomes such as hospitalisation and risk of developing cardiovascular disease, is an important area for future research.

2.7 What lessons can we apply from studies that have attempted to increase physical activity, to target sedentary behaviour in COPD?

In people with COPD, strategies that are capable of reducing the time spent in SB are unknown. Nevertheless, as studies which have shown some increase in PA in this population have included individual goal setting, collection of objective data on which to base goals and/or provide feedback, motivational interviewing, and frequent contact with a healthcare professional to increase motivation, overcome barriers and encourage adherence,[22-27] these approaches should be included in interventions to reduce time in SB. Further, being specific regarding the target behaviour is important. Data from a recent systematic review of 51 randomised controlled trials in diverse adult populations,[44] indicated that interventions which targeted SB were effective at reducing time spent in SB (mean difference 42 min/day, 95% confidence interval 5 to 79 min/day), whereas interventions which targeted PA alone or targeted PA in conjunction with time spent in SB did not change SB. Although it seems that interventions which specifically target time in SB may be more likely to reduce time in this domain, there are some data to suggest that such interventions will also increase PA. Studies that reduced SB in older adults have reported that time spent in SB was either replaced almost entirely with standing,[45] about half with standing and half with walking,[46] or two-thirds with light intensity PA and one-third with MVPA.[40] This suggests that, in people with COPD, an intervention which specifically targets a reduction in SB may also serve to increase PA.

Regarding the use of technology, in both people with and without COPD, studies that have demonstrated an increase in PA have often used devices such as pedometers, to provide a means of self-monitoring and a basis for feedback and goal setting.[22-26] Similar technology is available for self-monitoring of time spent in SB include pads for sitting time,[47] devices to monitor TV viewing time,[48] or wearable devices such as the Jawbone Up3™ (Jawbone, San Francisco, CA, USA; https://jawbone.com/). In young adults, the use of such technology as part of a behaviour change approach has been shown to result in large changes in time spent in SB.[49]

In the same way as technology has improved the ability to measure PA in people with COPD, there are now devices which produce highly accurate measures of sitting and lying time, and allow time in SB to be an outcome in both clinical and research settings. The activPAL™ (PAL Technologies Ltd, Glasgow, Scotland, UK) device is worn on the thigh and accurately measures time spent sitting or lying down, standing and walking.[50] This has recently been enhanced with a vibro-tactile function on the activPAL VT (VTaP) which provides real-time feedback on SB to the wearer. It is set to vibrate after a pre-specified amount of time that the wearer is sitting or lying down (the feature can be turned off while the wearer is asleep). A further iteration of the VTaP is the SitFIT which is being evaluated as part of the EuroFIT project (http://eurofitfp7.eu/). This device provides people with visual feedback on cumulative sitting time, upright time, steps, and duration of current sitting bout, in addition to the vibro-tactile feedback and can be worn on the waist or in a pocket. Studies exploring the effect of a behaviour change approach which targets a reduction in SB, which includes the use of these technologies, are needed in COPD.

2.8 Developing theory-informed interventions to reduce sedentary behaviour and increase light intensity physical activity for people with COPD

Healthcare professionals can draw from health psychology and the behavioural sciences to develop theory-informed behavioural interventions that meet the individual needs of people with COPD.[51] Having selected the target behaviour (e.g., SB in the household) and specified the change (e.g., stand up and move after 30 minutes of sitting), the key task is to understand the nature of the target behaviour because this information provides clarification on those components of the behaviour that are required to achieve change.[52] Guided by the theoretical models,[53] behaviour is determined by a system of three interacting features: physical or psychological *capabilities* to enact the behaviour, *opportunities* in the physical and social environment to execute the behaviour, and volitional (e.g., planning, evaluating) and automatic processes (e.g., emotional responses, habits) that provide the *motivation* for the direction and intensity of behaviour.[53] For example, people with COPD may be able to move from sitting into standing and undertake light intensity PA with minimal dyspnoea (*capability*), but lack an awareness of the health risks of SB and knowledge of how to break up SB during waking hours because it is not central to patient education (*motivation*),[54] yet have opportunities in their home (e.g., when watching television, stand up and walk around the room during each advertisement break) to accumulate no more than 30 minutes of SB in a single bout during waking hours (*opportunity*).

With a clear understanding of the nature of the target behaviour, healthcare professionals can utilise behaviour change concepts to design a comprehensive and individualised behaviour change intervention.[53] Figure 2 illustrates the nine intervention functions that may be utilised to effect change (see red wheel, Figure 2) and seven policy categories that influence the effectiveness of the nine intervention functions (see grey wheel, Figure 2). Guidance and standardised definitions regarding specific behavioural change techniques, such as feedback and monitoring, goals and planning, social support, self-belief and regulation, which can address these intervention functions are offered in the Behaviour Change Technique Taxonomy.[55] A case example illustrating how the behaviour change wheel can assist in identifying of the most appropriate mix of techniques to influence behaviour is detailed in Table 2 (adapted from Martin et al).[56]

3 Conclusions

Although the health benefits associated with participating in MVPA are well established, the goal of participating in ≥ 150 minutes of MVPA each week may not be realistic for people with COPD. For this reason, an intermediate goal, which focuses on reducing the time spent in SB and increased participation in light intensity PA is appropriate. Those studies which have reported some change in PA in this population have often provided individual goal setting, collection of objective physical activity data on which to base goals and/or provide feedback, motivational interviewing, frequent contact with a healthcare professional to increase motivation, overcome barriers and encourage adherence.[22-27] Therefore, these approaches need to be considered in interventions to reduce time in SB and increase participation in light intensity PA. Although there is no evidence for the effect of exercise training on SB in this population, such programs represent an ideal opportunity to initiate changes in health behaviours as they allow people with COPD to interact regularly with healthcare professionals. Future studies should use a theory-informed and systematic approach when designing a behaviour change intervention that aims to reduce time in SB and increase participation in light intensity PA.

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References

1 Watz H, Pitta F, Rochester CL, Garcia-Aymerich J, ZuWallack R, Troosters T, Vaes AW, Puhan MA, Jehn M, Polkey MI, Vogiatzis I, Clini EM, Toth M, Gimeno-Santos E, Waschki B, Esteban C, Hayot M, Casaburi R, Porszasz J, McAuley E, Singh SJ, Langer D, Wouters EF, Magnussen H, Spruit MA. An official European Respiratory Society statement on physical activity in COPD. *Eur Respir J.* 2014; **44**: 1521-37.

2 Cindy Ng LW, Mackney J, Jenkins S, Hill K. Does exercise training change physical activity in people with COPD? A systematic review and meta-analysis. *Chron Respir Dis.* 2012; **9**: 17-26.

3 Hill K, Gardiner PA, Cavalheri V, Jenkins SC, Healy GN. Physical activity and sedentary behaviour: applying lessons to chronic obstructive pulmonary disease. *Intern Med J.* 2015; **45**: 474-82.

4 Biswas A, Oh PI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, Alter DA. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med.* 2015; **162**: 123-32.

5 Chau JY, Grunseit AC, Chey T, Stamatakis E, Brown WJ, Matthews CE, Bauman AE, van der Ploeg HP. Daily sitting time and all-cause mortality: a meta-analysis. *PLoS One.* 2013; **8**: e80000.

6 van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. *Arch Intern Med.* 2012; **172**: 494-500.

7 Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc.* 2011; **43**: 1334-59.

8 Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR, Jr., Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Med Sci Sports Exerc.* 2011; **43**: 1575-81.

9 Sedentary Behaviour Research Network. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours". *Appl Physiol Nutr Metab.* 2012; **37**: 540-2.

10 Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med.* 2005; **171**: 972-7.

11 Vorrink SN, Kort HS, Troosters T, Lammers JW. Level of daily physical activity in individuals with COPD compared with healthy controls. *Respir Res.* 2011; **12**: 33.

12 Hartman JE, Boezen HM, de Greef MH, Ten Hacken NH. Physical and psychosocial factors associated with physical activity in patients with chronic obstructive pulmonary disease. *Arch Phys Med Rehabil.* 2013; **94**: 2396-402 e7.

13 Pitta F, Troosters T, Probst VS, Spruit MA, Decramer M, Gosselink R. Physical activity and hospitalization for exacerbation of COPD. *Chest.* 2006; **129**: 536-44.

14 O'Donovan G, Blazevich AJ, Boreham C, Cooper AR, Crank H, Ekelund U, Fox KR, Gately P, Giles-Corti B, Gill JM, Hamer M, McDermott I, Murphy M, Mutrie N, Reilly JJ, Saxton JM, Stamatakis E. The ABC of Physical Activity for Health: a consensus statement from the British Association of Sport and Exercise Sciences. *J Sports Sci.* 2010; **28**: 573-91.

15 Kushi LH, Doyle C, McCullough M, Rock CL, Demark-Wahnefried W, Bandera EV, Gapstur S, Patel AV, Andrews K, Gansler T, American Cancer Society N, Physical Activity Guidelines Advisory C. American Cancer Society Guidelines on nutrition and physical activity for cancer prevention: reducing the risk of cancer with healthy food choices and physical activity. *CA Cancer J Clin.* 2012; **62**: 30-67.

16 Inaba Y, Chen JA, Bergmann SR. Prediction of future cardiovascular outcomes by flow-mediated vasodilatation of brachial artery: a meta-analysis. *Int J Cardiovasc Imaging.* 2010; **26**: 631-40.

17 Brown JC, Winters-Stone K, Lee A, Schmitz KH. Cancer, physical activity, and exercise. *Compr Physiol.* 2012; **2**: 2775-809.

18 Garcia-Rio F, Rojo B, Casitas R, Lores V, Madero R, Romero D, Galera R, Villasante C. Prognostic value of the objective measurement of daily physical activity in patients with COPD. *Chest.* 2012; **142**: 338-46.

19 Waschki B, Kirsten A, Holz O, Muller KC, Meyer T, Watz H, Magnussen H. Physical activity is the strongest predictor of all-cause mortality in patients with COPD: a prospective cohort study. *Chest.* 2011; **140**: 331-42.

20 Garcia-Aymerich J, Lange P, Benet M, Schnohr P, Anto JM. Regular physical activity reduces hospital admission and mortality in chronic obstructive pulmonary disease: a population based cohort study. *Thorax.* 2006; **61**: 772-8.

21 McCarthy B, Casey D, Devane D, Murphy K, Murphy E, Lacasse Y. Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database Syst Rev.* 2015; **2**: CD003793.

22 Altenburg WA, ten Hacken NH, Bossenbroek L, Kerstjens HA, de Greef MH, Wempe JB. Short- and long-term effects of a physical activity counselling programme in COPD: a randomized controlled trial. *Respir Med.* 2015; **109**: 112-21.

23 Kawagoshi A, Kiyokawa N, Sugawara K, Takahashi H, Sakata S, Satake M, Shioya T. Effects of low-intensity exercise and home-based pulmonary rehabilitation with pedometer feedback on physical activity in elderly patients with chronic obstructive pulmonary disease. *Respir Med.* 2015; **109**: 364-71.

24 Mendoza L, Horta P, Espinoza J, Aguilera M, Balmaceda N, Castro A, Ruiz M, Diaz O, Hopkinson NS. Pedometers to enhance physical activity in COPD: a randomised controlled trial. *Eur Respir J.* 2015; **45**: 347-54.

25 Moy ML, Weston NA, Wilson EJ, Hess ML, Richardson CR. A pilot study of an Internet walking program and pedometer in COPD. *Respir Med.* 2012; **106**: 1342-50.

26 Hospes G, Bossenbroek L, Ten Hacken NH, van Hengel P, de Greef MH. Enhancement of daily physical activity increases physical fitness of outclinic COPD patients: results of an exercise counseling program. *Patient Educ Couns.* 2009; **75**: 274-8.

27 Wewel AR, Gellermann I, Schwertfeger I, Morfeld M, Magnussen H, Jorres RA. Intervention by phone calls raises domiciliary activity and exercise capacity in patients with severe COPD. *Respir Med.* 2008; **102**: 20-6.

28 Rosenberg M, Mills C, McCormack G, Martin K, Grove B, Pratt S, Braham R. Physical Activity Levels of Western Australian Adults 2009: Findings from the Physical Activity Taskforce Adult Physical Activity Survey. Health Promotion Evaluation Unit, The University of Western Australia, Perth, http://www.beactive.wa.gov.au/assets/files/Research/2009%20Adult%20Survey%20Main%20Report.pdf, 2010.

29 Vestbo J, Hurd SS, Agusti AG, Jones PW, Vogelmeier C, Anzueto A, Barnes PJ, Fabbri LM, Martinez FJ, Nishimura M, Stockley RA, Sin DD, Rodriguez-Roisin R. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. *Am J Respir Crit Care Med.* 2013; **187**: 347-65.

30 Hill K, Dolmage TE, Woon L, Coutts D, Goldstein R, Brooks D. Defining the relationship between average daily energy expenditure and field-based walking tests and aerobic reserve in COPD. *Chest.* 2012; **141**: 406-12.

31 Donaire-Gonzalez D, Gimeno-Santos E, Balcells E, Rodriguez DA, Farrero E, de Batlle J, Benet M, Ferrer A, Barbera JA, Gea J, Rodriguez-Roisin R, Anto JM, Garcia-Aymerich J. Physical activity in COPD patients: patterns and bouts. *Eur Respir J.* 2013; **42**: 993-1002.

32 van Remoortel H, Camillo CA, Langer D, Hornikx M, Demeyer H, Burtin C, Decramer M, Gosselink R, Janssens W, Troosters T. Moderate intense physical activity

depends on selected Metabolic Equivalent of Task (MET) cut-off and type of data analysis. *PLoS One.* 2013; **8**: e84365.

33 Goto C, Higashi Y, Kimura M, Noma K, Hara K, Nakagawa K, Kawamura M, Chayama K, Yoshizumi M, Nara I. Effect of different intensities of exercise on endothelium-dependent vasodilation in humans: role of endothelium-dependent nitric oxide and oxidative stress. *Circulation.* 2003; **108**: 530-5.

34 Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, Owen N. Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. *Diabetes Care.* 2007; **30**: 1384-9.

35 Healy GN, Wijndaele K, Dunstan DW, Shaw JE, Salmon J, Zimmet PZ, Owen N. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care.* 2008; **31**: 369-71.

36 Chau JY, Grunseit A, Midthjell K, Holmen J, Holmen TL, Bauman AE, Van der Ploeg HP. Sedentary behaviour and risk of mortality from all-causes and cardiometabolic diseases in adults: evidence from the HUNT3 population cohort. *Br J Sports Med.* 2013.

37 Loprinzi PD, Lee H, Cardinal BJ. Evidence to support including lifestyle light-intensity recommendations in physical activity guidelines for older adults. *Am J Health Promot.* 2015; **29**: 277-84.

38 Healy GN, Matthews CE, Dunstan DW, Winkler EA, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. *Eur Heart J.* 2011; **32**: 590-7.

39 Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, Owen N. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care.* 2008; **31**: 661-6.

40 Gardiner PA, Eakin EG, Healy GN, Owen N. Feasibility of reducing older adults' sedentary time. *Am J Prev Med.* 2011; **41**: 174-7.

41 Stand up for your health. Diabetes Queensland. http://www.diabetesqld.org.au/healthy-living/healthy-u/stand-up-for-your-health.aspx. Accessed: 11 may 2015.

42 Australia's Physical Activity & Sedentary Behaviour Guidelines for Adults. Australian Government. Department of Health. http://www.health.gov.au/internet/main/publishing.nsf/Content/health-pubhlth-strateg-phys-act-guidelines#apaadult. Accessed: 11 May 2015.

43 Park SK, Larson JL. The relationship between physical activity and metabolic syndrome in people with chronic obstructive pulmonary disease. *J Cardiovasc Nurs.* 2014; **29**: 499-507.

44 Martin A, Fitzsimons C, Jepson R, Saunders DH, van der Ploeg HP, Teixeira PJ, Gray CM, Mutrie N, Euro FITc. Interventions with potential to reduce sedentary time in adults: systematic review and meta-analysis. *Br J Sports Med.* 2015.

45 Rosenberg DE, Gell NM, Jones SM, Renz A, Kerr J, Gardiner PA, Arterburn D. The Feasibility of Reducing Sitting Time in Overweight and Obese Older Adults. *Health Educ Behav.* 2015.

46 Fitzsimons CF, Kirk A, Baker G, Michie F, Kane C, Mutrie N. Using an individualised consultation and activPAL feedback to reduce sedentary time in older Scottish adults: results of a feasibility and pilot study. *Prev Med.* 2013; **57**: 718-20.

47 Ryde GC, Gilson ND, Suppini A, Brown WJ. Validation of a novel, objective measure of occupational sitting. *J Occup Health.* 2012; **54**: 383-6.

48 Otten JJ, Jones KE, Littenberg B, Harvey-Berino J. Effects of television viewing reduction on energy intake and expenditure in overweight and obese adults: a randomized controlled trial. *Arch Intern Med.* 2009; **169**: 2109-15.

49 Barwais FA, Cuddihy TF. Empowering sedentary adults to reduce sedentary behavior and increase physical activity levels and energy expenditure: a pilot study. *Int J Environ Res Public Health.* 2015; **12**: 414-27.

50 Grant PM, Ryan CG, Tigbe WW, Granat MH. The validation of a novel activity monitor in the measurement of posture and motion during everyday activities. *Br J Sports Med.* 2006; **40**: 992-7.

51 Atkins L, Michie S. Changing eating behaviour: What can we learn from behavioural science? *Nutrition Bulletin.* 2013; **38**: 30-5.

52 Michie S, West R, Spring B. Moving from theory to practice and back in social and health psychology. *Health Psychol.* 2013; **32**: 581-5.

53 Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011; **6**: 42.

54 Stoilkova A, Janssen DJ, Wouters EF. Educational programmes in COPD management interventions: a systematic review. *Respir Med.* 2013; **107**: 1637-50.

55 Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, Eccles MP, Cane J, Wood CE. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Ann Behav Med.* 2013; **46**: 81-95.

56 Martin R, Murtagh EM. An intervention to improve the physical activity levels of children: Design and rationale of the 'Active Classrooms' cluster randomised controlled trial. *Contemp Clin Trials.* 2015; **41**: 180-91.

Figures legends

Figure 1: Light, moderate and vigorous intensity physical activities

Figure 2: Behaviour change wheel. The green wheel (at the core) represents the COM-B model, which comprises the three features of capability, opportunity and motivation. The red wheel (middle) represents nine intervention functions which can be used to effect behaviour change. The grey wheel (outermost) represent the seven policy categories that may influence the effectiveness of the nine intervention functions. See Table 2 for an example of how this wheel may assist in designing a behaviour change intervention to reduce sedentary behaviour and increase light intensity physical activity in someone with chronic obstructive pulmonary disease. This Figure has been reproduced with permission from Michie, S. et al 2011 (Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011; **6**: 42).

Table 1: A comparison of the difference in cut-points for defining moderate, vigorous and greater than vigorous intensity physical activity, defined using absolute and relative values (adapted from Garber, C.E. et al, 2011).[7]

Case study: Mr H is a 69 year old with COPD (FEV_1 = 45% predicted, weight = 75 kg), who completed an incremental cycle ergometry test this morning. He achieved a peak rate of oxygen uptake = 12 $ml \cdot kg^{-1} \cdot min^{-1}$ (3.4 METs).

	Absolute cut-points	**Relative cut-points**
Moderate intensity PA	3.0 to < 6.0 METs	46 to 63% of VO_2peak: 1.6 to < 2.2 METs
Vigorous intensity PA	6.0 to 8.7 METs	64 to 90% of VO_2peak: 2.2 to 3.1 METs
Near maximal to maximal intensity PA	≥ 8.8 METs	≥ 91% of VO_2peak ≥ 3.2 METs

Abbreviations: COPD: chronic obstructive pulmonary disease; FEV_1: forced expiratory volume in one second; METs: metabolic equivalent of task; PA: physical activity; VO_2peak: peak rate of oxygen uptake.

Table 2: An example of how intervention functions (see red wheel in Figure 2) can be guided by the COM-B framework (see green wheel in Figure 2) (adapted from Martin, R. and Murtagh EM, 2015).[56]

Case study: Mr H is a 69 year old with COPD (FEV_1 = 45% predicted) who reports marked dyspnoea on exertion during his daily life. He has recently completed a six-minute walk test, during which he walked 300 m (end-test dyspnoea = 5/10). He needed to rest once during the test due to intolerable dyspnoea.

			Intervention functions								
Behaviour source (from COM-B)	**Why are people with COPD sedentary?**	**If change is required, what needs to be done?**	**Ed**	**Ps**	**In**	**Co**	**Tr**	**Re**	**ER**	**Mod**	**En**
Physical capability	Reduced exercise capacity and marked dyspnoea on exertion	Supervised exercise training					✓				

Psychological capability	Exhibits fear avoidance behaviours, such as minimal participation in any form of physical activity due to risk of experiencing severe dyspnoea	Supervised exercise training offered together with education Possible cognitive behavioural therapy	✓				✓				✓
Volitional motivation	Does not understand the deleterious effects associated with sedentary behaviour	Education on this topic	✓	✓							
Automatic motivation	Sedentary behaviour has become habitual and the patient believes that people with COPD cannot participate in any form of physical	Patient attends a rehabilitation program during which others share their experiences of reducing time in sedentary behaviour and breaking up sedentary behaviour with light		✓						✓	

	activity	intensity physical activity, despite having lung disease									
Opportunities in physical environment	Patient does the ironing seated on chair Patient uses the TV remote control to change the TV channel or turn the TV volume up/down. Patient's wife prepares evening meal	Encourage patient to do the ironing in standing Encourage patient to stand up and walk to the TV to change the TV channel or turn the TV volume up/down Encourage patient (and his wife) to allow patient to assist with meal preparation (e.g. chopping vegetables)		✓							✓
Opportunities in	Spouse offers to undertake all	Encourage spouse to attend	✓	✓					✓		

social environment	domestic duties so that her husband can ‘sit and rest’	education session on the deleterious effects associated with sedentary behaviour									

Definition of abbreviations: 6MWD: six-minute walk distance; COPD: chronic obstructive pulmonary disease; Co: coercion; Ed: education; En: enablement; ER: environmental restructuring; FEV_1: forced expiratory volume in one second; In: incentivisation; Mod: modelling; Ps: persuasion; psych: psychological capability; Re: restriction; Tr: training