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

Vinicius Cavalheri¹,² (BSc Physiotherapy, MSc, PhD), Leon Straker¹ (BAppSc, MSc, PhD), Daniel F. Gucciardi¹ (BSc (Hons) Psychology, PhD), Paul A. Gardiner³,⁴ (BSc (Hons), PhD), Kylie Hill¹,² (BSc Physiotherapy, PhD)

¹ School of Physiotherapy and Exercise Science, Faculty of Health Science, Curtin University, Perth, Western Australia
² Institute for Respiratory Health, University of Western Australia, Perth, Western Australia
³ The University of Queensland, School of Public Health, Brisbane, Queensland
⁴ Mater Research Institute - The University of Queensland, Brisbane, Queensland

CORRESPONDING AUTHOR

Dr Kylie Hill
Associate Professor
School of Physiotherapy and Exercise Science
Curtin University, GPO Box U1987
Perth, Western Australia, Australia, 6845
Tel: +61 8 9266 2774, Fax: +61 8 9266 3699
Email: K.Hill@curtin.edu.au
The Authors:

Vinicius Cavalheri: Vinicius is a Lecturer in the School of Physiotherapy and Exercise Science at Curtin University. He has an interest in exploring patterns of physical activity and sedentary behaviour in adults with chronic obstructive pulmonary disease and lung cancer.

Leon Straker: Leon is a John Curtin Distinguished Professor in the School of Physiotherapy and Exercise Science at Curtin University. His research focusses on the impact of technology on human health, particularly sedentary behaviour and physical activity.

Daniel Gucciardi: Daniel is a Senior Research Fellow in the School of Physiotherapy and Exercise Science at Curtin University. He is interested in psycho-social variables that influence and are influenced by health behaviours in general and clinical populations.

Paul Gardiner: Paul is a Postdoctoral Research Fellow in the School of Public Health at The University of Queensland. His research focuses on understanding and influencing sedentary behaviour in older adults and people with chronic disease.

Kylie Hill: Kylie is an Associate Professor in the School of Physiotherapy and Exercise Science at Curtin University. She has an interest in exploring patterns of physical activity and sedentary behaviour in adults with chronic respiratory 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).\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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\textsuperscript{7, 8} (Figure 1). Activities or behaviours (other than sleep) that require low energy expenditure ($\leq 1.5$ METs) and are undertaken in sitting or a reclined posture, are classified as SB.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{7,14,15} Health benefits associated with 
participating in \textit{\geq} 150 minutes per week of MVPA include reductions in cardiovascular
and metabolic disease, risk of developing some cancers and all-cause mortality.\textsuperscript{7, 14, 15} Closer to 300 minutes of MVPA is required for prevention of weight gain and obesity.\textsuperscript{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,\textsuperscript{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,\textsuperscript{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.\textsuperscript{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 \( \geq 30 \) minutes of MVPA on \( \geq \) five days each week, accrued in bouts \( \geq 10 \) minutes.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{29} Earlier work has demonstrated that people with moderate COPD (FEV\textsubscript{1} = 50 \pm 16\%) have a peak aerobic capacity equivalent to 5.0 \pm 1.0 METs (peak rate of oxygen uptake [VO\textsubscript{2peak}] = 17.4 \pm 3.8 ml\cdotkg\textsuperscript{-1}\cdotmin\textsuperscript{-1}).\textsuperscript{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. \geq 6.0 METs). In fact, their capacity to participate in moderate intensity activity is grossly limited, as moderate intensity PA (defined as activity requiring \geq 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).\textsuperscript{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\textsubscript{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).\textsuperscript{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,\textsuperscript{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.\textsuperscript{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.\textsuperscript{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. 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. As time in SB is almost perfectly inversely related to time spent in light intensity PA, it seems likely that any reduction in SB will result in an increase in light intensity PA, which has been associated with health benefits. 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. 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. 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) and recommendations about reducing SB and breaking up periods of sitting now appear in guidelines for Australians.
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. An increase in SB occurs both during hospitalisation and at one month following hospitalisation for an acute exacerbation, 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, 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 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, about half with standing and half with walking, or two-thirds with light intensity PA and one-third with MVPA. 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. Similar technology is available for self-monitoring of time spent in SB include pads for sitting time, devices to monitor TV viewing time, 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.

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. 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.\textsuperscript{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.\textsuperscript{52} Guided by the theoretical models,\textsuperscript{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.\textsuperscript{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), 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. 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. 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.).
3 Conclusions

Although the health benefits associated with participating in MVPA are well established, the goal of participating in $\geq 150$ 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.\textsuperscript{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.

Acknowledgements

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References


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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·kg$^{-1}$·min$^{-1}$ (3.4 METs).

<table>
<thead>
<tr>
<th></th>
<th>Absolute cut-points</th>
<th>Relative cut-points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate intensity PA</td>
<td>3.0 to &lt; 6.0 METs</td>
<td>46 to 63% of VO$_2$peak:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.6 to &lt; 2.2 METs</td>
</tr>
<tr>
<td>Vigorous intensity PA</td>
<td>6.0 to 8.7 METs</td>
<td>64 to 90% of VO$_2$peak:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2 to 3.1 METs</td>
</tr>
<tr>
<td>Near maximal to maximal</td>
<td>≥ 8.8 METs</td>
<td>≥ 91% of VO$_2$peak</td>
</tr>
<tr>
<td>intensity PA</td>
<td></td>
<td>≥ 3.2 METs</td>
</tr>
</tbody>
</table>

Abbreviations: COPD: chronic obstructive pulmonary disease; FEV$_1$: forced expiratory volume in one second; METs: metabolic equivalent of task; PA: physical activity; VO$_2$peak: 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).

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.

<table>
<thead>
<tr>
<th>Behaviour source (from COM-B)</th>
<th>Why are people with COPD sedentary?</th>
<th>If change is required, what needs to be done?</th>
<th>Ed</th>
<th>Ps</th>
<th>In</th>
<th>Co</th>
<th>Tr</th>
<th>Re</th>
<th>ER</th>
<th>Mod</th>
<th>En</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical capability</td>
<td>Reduced exercise capacity and marked dyspnoea on exertion</td>
<td>Supervised exercise training</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>✓</td>
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<td></td>
</tr>
</tbody>
</table>

28
<table>
<thead>
<tr>
<th>Psychological capability</th>
<th>Exhibits fear avoidance behaviours, such as minimal participation in any form of physical activity due to risk of experiencing severe dyspnoea</th>
<th>Supervised exercise training offered together with education Possible cognitive behavioural therapy</th>
<th>✓</th>
<th>✓</th>
<th>✓</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volitional motivation</td>
<td>Does not understand the deleterious effects associated with sedentary behaviour</td>
<td>Education on this topic</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automatic motivation</td>
<td>Sedentary behaviour has become habitual and the patient believes that people with COPD cannot participate in any form of physical</td>
<td>Patient attends a rehabilitation program during which others share their experiences of reducing time in sedentary behaviour and breaking up sedentary behaviour with light</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Opportunities in physical environment</td>
<td>activity</td>
<td>intensity physical activity, despite having lung disease</td>
<td></td>
<td></td>
<td></td>
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<td>--------------------------------------</td>
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<td>--------------------------------------------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Patient does the ironing seated on chair</td>
<td>Patient uses the TV remote control to change the TV channel or turn the TV volume up/down. Patient’s wife prepares evening meal</td>
<td>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)</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spouse offers to undertake all</td>
<td>Encourage spouse to attend</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>social environment</td>
<td>domestic duties so that her husband can ‘sit and rest’</td>
<td>education session on the deleterious effects associated with sedentary behaviour</td>
<td></td>
<td></td>
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</tbody>
</table>

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