Title

Physical activity and sedentary behaviour: applying lessons learned to chronic

obstructive pulmonary disease

Short title

Activity & sitting: lessons learned for COPD

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Contributions

Kylie Hill contributed to the intellectual planning and writing of the paper. Paul Gardiner contributed to the intellectual planning and writing of the paper. Vinicius Cavalheri contributed to the intellectual planning and writing of the paper. Sue Jenkins contributed to the intellectual planning and writing of the paper. Genevieve Healy contributed to the intellectual planning and writing of the paper. All authors have approved the final version of the manuscript.

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Abstract

In health and disease, the benefits of regular participation in moderate to vigorous intensity physical activity are well documented. However, individuals with chronic conditions, such as those with chronic obstructive pulmonary disease (COPD), typically do very little activity at a moderate or vigorous intensity. Much of their day is instead spent in sedentary behaviour, such as sitting or reclining, which requires very little energy expenditure. This high level of time spent in sedentary behaviour can have serious health consequences, including increased risk of diabetes, cardiovascular disease and premature mortality. There is emerging evidence to suggest that participation in light intensity physical activities (e.g. standing or slow walking) may have benefits for cardio-metabolic health. Given the low aerobic capacity of individuals with moderate to severe COPD, increasing light intensity activity (through reducing sedentary time) may be a feasible additional strategy to improve health in this population, alongside traditional recommendations to increase the time spent in moderate to vigorous intensity physical activity. This review provides an overview of physical activity and sedentary behaviour, with a particular emphasis on these behaviours for people with COPD. It provides suggestions for the measurement of these behaviours within the clinical setting, as well as for interventions that may be effective at increasing physical activity and reducing sedentary behaviour in this population.

Key words

Physical activity, sedentary behaviour, chronic obstructive pulmonary disease

Introduction

The widespread benefits of regular participation in moderate to vigorous intensity physical activity are well established.[1] However, consistent with international data, the majority of Australian adults fail to meet the recommended levels of physical activity to produce health benefits.[2] This high level of inactivity contributes significantly to healthcare costs.[3] Recently there has been a focus on sedentary behaviour, or *too much sitting*. Specifically, there is growing evidence that excessive sedentary time, in particular time accumulated in uninterrupted bouts of sedentary behaviour, is associated with adverse health outcomes.[4,5] Individuals with chronic obstructive pulmonary disease (COPD) typically engage in very little physical activity due to exertional dyspnoea and fatigue. Although pulmonary rehabilitation, which has a focus on exercise training, has strong evidence for reducing symptoms, improving exercise tolerance and quality of life,[6] and reducing healthcare utilisation[7] in this patient population, there is limited evidence that pulmonary rehabilitation increases daily levels of physical activity and reduces sedentary time.

This review provides an overview of the health benefits of physical activity across the spectrum, from light intensity through to moderate and vigorous intensity, as well as the adverse health effects of too much time spent in sedentary behaviour. It includes a summary of the methods used to measure physical activity and sedentary behaviour in research and clinical settings. Estimates of time spent in physical activity and sedentary behaviour by people with COPD are described as well as some direct and 'stealth' interventions that aim to increase physical activity and reduce sedentary behaviour.

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Physical activity: definition and measurement

Physical activity is defined as any bodily movement generated by skeletal muscle that results in energy expenditure.[1] It is often classified as light, moderate or vigorous intensity, according to the level of energy expenditure required (Figure 1)[8]. Multiple different behaviours fall under these intensity classifications. For example, light intensity physical activity would include activities such as showering and ironing.[9] In contrast, vigorous intensity physical activity would include activities such as running and walking uphills.[9] Physical activity may also be classified as activities undertaken as part of daily living, such as domestic and occupational tasks, or as exercise, which is a form of physical activity that is planned, structured and undertaken regularly with the goal of improving or maintaining fitness.[1]

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Obtaining accurate and detailed measures of physical activity are useful when designing and evaluating interventions to optimise activity levels. Measures of physical activity can broadly be grouped into subjective (i.e. self-report) and objective. Subjective measures rely on an individual's recall of their activity levels. Although data obtained via subjective measures, such as questionnaires, may lack precision,[10] detailed questioning over recent time periods has been shown to improve the reliability of the data obtained.[11] Subjective measures also offer the opportunity to obtain detailed

information regarding the type of activities undertaken during daily life, which allows clinicians to establish targets and goals regarding participation in physical activity, based on individual preferences. The low cost associated with self-report measures of physical activity has resulted in their widespread use in clinical practice and epidemiological research.

Objective measures involve using a device, commonly a motion sensor, to capture physical activity. Devices range in complexity and price. The most basic option is a pedometer, which records the number of steps taken. More sophisticated devices may use accelerometry to measure movement and/or non-invasive physiological sensors to estimate energy expenditure. The measurement properties of these devices and their output vary considerably. Most devices require technical expertise to collect, download and interpret the data. Nevertheless, technology in this area is advancing quickly and it is likely that the collection of robust physical activity data via objective methods will be feasible for clinicians in the near future. Further information on the measurement of physical activity is available elsewhere.[12,13]

Health effects of moderate to vigorous physical activity

In adults, the benefits of regular participation in moderate to vigorous intensity physical activity have been well established and include a reduction in the risk of cardiovascular disease as well as all-cause mortality.[1] These effects are likely to be mediated by several mechanisms, including production, expression and release of myokines by the skeletal muscle, improvement in endothelial function, cardiovascular fitness and insulin sensitivity, maintenance of a healthy body weight, preservation of fat free mass and a

reduction in circulating systemic inflammatory biomarkers.[1,14] Evidence of health benefits has resulted in a range of public health messages designed to promote participation in daily physical activity, with current guidelines from the United States of America recommending that adults perform a minimum of 150 minutes of moderate intensity physical activity or 75 minutes of vigorous intensity physical activity each week.[1] However, despite the obvious health benefits of an active lifestyle, 31% of adults worldwide do not meet these guidelines and are considered physically inactive.[15] This high level of inactivity has serious public health and economic consequences, with low levels of physical activity increasing the risk of developing conditions such as obesity and type II diabetes.[1] Further, there is evidence to suggest that low levels of physical activity also play a part in the development of some cancers, dementia, and mood disturbances such as depression.[1] Overall, low levels of physical activity have been estimated to account for 9% of premature mortality, or more than 5.3 million deaths worldwide each year.[16]

What about time spent in activity other than moderate to vigorous physical activity?

To date, much of the public health research and resources have been targeted towards increasing population levels of moderate to vigorous intensity activity. However, on average, adults spend more than 90% of their waking day in activities *other* than those classified as moderate or vigorous intensity.[3] Even if an individual was to undertake the minimum of 30 minutes/day of moderate to vigorous intensity activity specified in public health guidelines,[1] time in this activity intensity would still constitute less than 5% of a typical 16-hour waking day. Accordingly, a more comprehensive view of

inactivity has increasingly penetrated research, policy and practice. This approach considers activities across a spectrum from sedentary, to light intensity activity to moderate and vigorous, with a focus on understanding the distribution and health effects across this range of physical activity (Figure 1).

Sedentary behaviour: definition and measurement

On average, the majority (46% to 59%) of adults spend their waking hours at the low end of the spectrum, that is, in sedentary behaviour.[3] Sedentary behaviours are defined both by low energy expenditure (<1.5 Metabolic Equivalent of Tasks [MET]) and a sitting or reclining posture.[17] They occur throughout the waking day (i.e. sleep is not considered a sedentary behaviour), and across work, leisure, domestic, and transport domains. Common behaviours that occur while sedentary include television viewing, reading, driving, using a computer, and playing cards. Importantly, an individual can be both physically active (i.e. meet the physical activity guidelines)[1] *and* highly sedentary; a concept coined "the active couch potato".[18] As outlined later, time spent in both physical activity and sedentary behaviour contributes to health outcomes.

As is the case for physical activity, both subjective and objective measures can be used to measure sedentary time. In addition to measuring the total time spent in sedentary behaviours, measures can also be used to assess behaviours within individuals and groups, in the context of the domains in which they occur. To date, self-report measures of time spent in sedentary behaviour have typically being used, with generally good reliability, but poor-to-modest validity.[19] More recently, methods such as past day recall show improved validity over previous recall periods, and may be useful for large-scale

implementation.[20] However, even a simple question, such as 'in the last week, how much time per day would you typically spend sitting down?' could be useful in a clinical setting to provide tailored advice and monitor changes over time.

Objective measures, such as those derived from accelerometers and inclinometers, have also been used to measure sedentary time. Importantly, these devices provide date and time stamped data, which enable analysis of not only the total amount of time spent in sedentary behaviours, but also how and when the sedentary time was accumulated. Ideally, such measures derive sedentary time not only from low energy expenditure, but also posture in order to distinguish time spent sedentary (low energy, sitting or reclining posture) from time spent standing (low energy, upright posture). Postural-based measures, such as the activPAL[TM] monitor (PAL Technologies, Glasgow, UK), have been shown to be highly accurate compared to direct observation,[21] and their use is becoming more widespread within both intervention and observation research. However, these objective measures do not capture domain or behaviour-specific information; contextual information that is useful for the development of intervention targets aimed at individuals and public health messages on how to reduce sedentary time. Therefore, it is recommended that a combination of both self-report and objective measures is used.[19]

Health impacts of too much sitting

The last decade has seen rapid advances in our understanding of the relationship between time spent in sedentary behaviours and health outcomes. A recent review reported that those categorised in the most sedentary group, regardless of how it was

measured, had on average, twice the risk of developing type II diabetes or cardiovascular disease, or of dying from cardiovascular disease, and 1.5 times the risk of dying prematurely compared to those in the group who were the least sedentary.[5] Detrimental associations with excessive sedentary time have also been observed with weight gain, depressive symptoms, biomarkers of chronic disease risk (including triglycerides, HDL-cholesterol, and insulin), musculoskeletal symptoms, poor quality of life, and chronic kidney disease.[22] Notably, although those who are both inactive and have high sedentary time are at the highest risk, even in those who met physical activity guidelines (i.e. are 'active'), detrimental associations with sedentary time have been observed.[18] This highlights the need to measure both sedentary time and physical activity within lifestyle assessments. Mechanisms proposed for the associations observed include the minimal muscular contractions in the large postural muscles occurring during sitting,[23] together with the lower energy expenditure compared to non-sedentary behaviours.[24]

Importantly, it is not just total sedentary time that appears to be relevant for health, but also the manner in which it is accumulated. Regularly interrupting sedentary time, with either light or moderate intensity activity, has been beneficially associated with biomarkers of chronic disease.[25] Conversely, long, unbroken periods of sitting have been associated with increased insulin resistance and poor glycaemic control.[4,26] This evidence has informed the development of national and international recommendations to minimise the amount of time spent in prolonged sitting and to break up sitting as often as possible.[1,27] Although sufficient robust evidence regarding 'how often should

we get up?' is not yet available, a practical message may be to "sit less throughout the day, and stand up at least every 30 minutes."

If not sedentary, then what?

The strong negative correlations observed between sedentary time and light intensity physical activity[28] suggests that if we are not sedentary, we are typically undertaking light intensity activities. This highly heterogenous group of behaviours includes standing, incidental movement and slow walking; activities that are difficult to quantify via self-report measurement tools. Correspondingly, despite being high volume (on average, 37% to 46% of adults' waking hours),[3] little is known about the health effects of behaviours that fall within the light intensity physical activity spectrum. Nevertheless, associations observed with light intensity physical activity tend to be opposite to those demonstrated with sedentary time.[29] Of note, there is preliminary evidence to suggest that there are cardio-metabolic benefits for those who have a positive light-sedentary balance (i.e. more time is spent in light intensity physical activity than sedentary), even if recommended levels of moderate to vigorous intensity physical activity are not achieved.[29] Though it is ideal if adults have both low sedentary time, and high moderate to vigorous intensity physical activity time,[29] these findings collectively suggest that there may also be benefit from shifting sedentary time to light intensity activities; a potentially more feasible and acceptable target for change especially for those with chronic conditions such as COPD.

How are physical activity and sedentary time affected in people with chronic obstructive pulmonary disease?

Dyspnoea and fatigue during daily activities are frequently reported by people with COPD and appear to contribute to the low levels of physical activity undertaken in this population.[30] Specifically, there are now robust data showing that people with COPD participate in less physical activity when compared with healthy people of a similar age. One of the first studies reporting this difference using an objective measure of physical activity showed that people with COPD spent less time standing and walking when compared with healthy adults of a similar age and gender proportion (Figure 2).[31] A review of 11 studies that measured physical activity levels in people with COPD and healthy controls revealed that the proportion of time people with COPD spent participating in physical activity, relative to the healthy controls, was 57%.[32] The level of physical activity of people with COPD decreases with increased disease severity and in response to an acute exacerbation.[33,34]

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Besides engaging in lower levels of physical activity, people with COPD spend a large proportion of their waking hours sitting and lying down.[31] That is, compared to healthy controls, during waking hours, people with COPD spend nearly 25% more time sitting and 200% more time lying down (Figure 2).[31] In contrast to data on physical activity, sedentary time does not seem to differ across severities of COPD.[35] Of note, it appears that sitting time in this population is associated with lower exercise capacity, lower motivation to exercise and higher number of exacerbations in the past year.[35]

Health benefits of physical activity and consequences of low levels of physical activity in people with COPD

The benefits of participating in regular physical activity are not limited to the general population. Specifically, in people with COPD, regular participation in physical activity has been shown to reduce the risk of hospitalisation and lower all-cause mortality.[36] Higher levels of physical activity in those with COPD also appear to minimise extrapulmonary manifestations of the disease such as systemic inflammation and cardiac dysfunction.[37] The benefits of physical activity appear to be present prior to the development of COPD as current smokers who participate in regular physical activity have a reduced rate of decline in lung function.[38] Participation in low levels of physical activity by individuals with a chronic health condition is likely to have additional health consequences to those described in the general population. That is, in addition to the impairments imposed by the disease process itself, deconditioning of both the cardiovascular system and muscles of locomotion resulting from participation in low levels of physical activity often contributes to their decline in functional status.[39] This has led to an interest in the role of rehabilitative strategies that aim to optimise participation in physical activity in people with a chronic health condition.

How can we change physical activity and sedentary behaviour in people with COPD?

There are broadly two approaches to increasing physical activity; direct and 'stealth' interventions. Direct interventions use strategies to directly influence physical activity, while 'stealth' interventions may target other values and beliefs that extend beyond health to increase physical activity. Data pertaining to interventions that may improve

sedentary behaviour in people with COPD are scarce. Regarding physical activity, one direct intervention that has received attention in people with COPD is the use of exercise training, within the framework of pulmonary rehabilitation. Despite achieving strong evidence for reducing symptoms of dyspnoea and fatigue, increasing exercise capacity, improving quality of life,[6] and reducing hospitalisations related to acute exacerbations of COPD,[7] the effects of exercise training on physical activity appear to be limited. A systematic review and meta-analysis of seven studies (two randomised trials and five single-group interventional studies) examining the effect of exercise training on physical activity in a total of 472 people (419 males) with COPD demonstrated minimal change, with an overall effect size of 0.12 ($p = 0.01$),[40] which was equivalent to an increase of approximately five minutes per day. This small change may be because pulmonary rehabilitation programs lack an effective behavioural component that targets changes in physical activity outside of what people complete as part of their structured exercise.

Examining the effects of embedding psychosocial interventions in pulmonary rehabilitation programs is a promising area for future research and may have real potential for changing physical activity and sedentary time in people with compromised lung function.[41] A recent study in overweight and obese adults showed that combining a behavioural intervention with prescribed exercise increased physical activity more so than exercise prescription alone.[42] This would suggest the utility of this approach in people with chronic conditions. The recent Lancet series on physical activity contained a comprehensive review of approaches for increasing physical activity within different population groups, and found strong evidence for behavioural and social approaches.[43]

Interventions within the primary care setting are successful at increasing the self-reported physical activity levels of inactive individuals at 12 months, with recent reviews of physical activity interventions in adults[44] and older adults[45] reporting that interventions containing behavioural strategies such as goal setting, self-monitoring and feedback were most effective. Nevertheless, in people with COPD who are commencing a pulmonary rehabilitation program, the timing of such interventions may be critical given that for many people, it may be too much to commence a regular exercise program and at the same time undertake more physical activity in their daily life.

An example of an evidence-based behavioural approach used in the primary care setting is the 5As approach. This has been used widely in smoking cessation[46] and was adopted in the 2013 National Health and Medical Research Council clinical practice guidelines for the management of overweight and obesity in adults, adolescents and children in Australia as a useful framework for general practitioners to help obese patients manage their weight and is based on: *Assess* level of behaviour; *Advise* based upon personal health risks; *Agree* on a realistic set of goals; *Assist* to anticipate barriers and develop a specific action plan; and, *Arrange* follow-up support. Figure 3 contains an example of how this approach may be used in clinical practice to influence sedentary behaviour.

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Rather than direct interventions to increase physical activity, it is possible that 'stealth' interventions, such as reducing time spent in sedentary behaviours (e.g., television viewing)[47] in order to increase physical activity may offer greater success in people with COPD. This fits nicely with the premise that sedentary behaviour is a new health behaviour change target in its own right. While most sedentary behaviour interventions have been conducted with children and adolescents, emerging evidence suggests the utility of this stealth approach in adults. Three studies (all in non-COPD populations) are worth noting here. TView evaluated a three week program using an electronic television lock-out system with 36 overweight and obese participants aged 22 to 61 years.[48] Stand Up For Your Health[49] took a whole-of-day approach to reduce and interrupt prolonged sedentary time, targeting television time as well as other sedentary behaviours such as sitting and reading, or engaging in computer use. This single group feasibility study conducted over two weeks with 59 older adults (aged 60 to 92 years) used a face-to-face goal-setting consultation and one tailored mailing.[49] The final single group feasibility study was conducted with 24 older adults (aged mean $\pm$ SD, 68 $\pm$ 6 years) and also used a face-to-face consultation and feedback on sedentary time as part of the intervention.[50] All three interventions achieved around a 30-minute per day reduction in sedentary time (24 to 37 minutes per day), of which approximately one-third (7 to 13 minutes per day) of this time was reallocated to moderate to vigorous intensity physical activity.

The findings from these studies suggest that changes in sedentary time are achievable and that increases in physical activity are likely. The appeal of these approaches is that they are simple, achievable and unlikely to do any harm. Environmental changes, such

as devices to limit the amount of TV a person watches, may be difficult to implement,

however behavioural approaches produced similar changes in sedentary time. The

consultation sessions in the two feasibility studies [48] [49] used concepts from the 5As

approach in that they: *assessed* participants' level of sedentary time (using devices);

advised participants of the pros and cons of reducing sedentary time; *agreed* on a set of

goals (in conjunction with the participants); and *assisted* with overcoming barriers. No

arrangements were made for follow-up support. These interventions took an average of

45 minutes[49] and 30 minutes[50] to deliver. The appeal of these approaches is that they are

simple, achievable and unlikely to do any harm. However, randomized trials of longer-

term interventions are needed to evaluate intervention efficacy in a range of

populations. While these studies were conducted in non-COPD populations, they were

in overweight and obese and older adult populations with a range of chronic conditions.

Earlier work has suggested that people with COPD utilise 58% of their aerobic capacity

to complete usual activities of daily living.[51] This is considerably more than individuals

with normal aerobic capacity, who have been estimated to utilise 40% of their aerobic

capacity during usual activities of daily living.[52] Given the limited aerobic capacity of

individuals with COPD, an intervention focussed on increasing light intensity physical

activity and breaking up time spent in sedentary behaviour may be more appropriate in

this population than one focused primarily on increasing time spent in moderate to

vigorous intensity physical activity. The development of such interventions – a key area

for future research in individuals with COPD – should consider the approaches

described above (i.e., the 5As; stealth interventions) in conjunction with evidence based

intervention strategies (e.g., motivational interviewing; self-monitoring) for behaviour change.

Conclusion

This paper has reviewed the benefits of physical activity and the adverse effects of sedentary behaviour. Exertional dyspnoea and fatigue pose additional challenges for people with COPD when attempting to undertake physical activity. Strategies are needed to assist both healthy individuals and those with chronic conditions such as COPD to: (i) increase the time spent in physical activity (which includes activity across the intensity spectrum); (ii) reduce total time spent sitting; and, (iii) break up any periods of prolonged sitting across the day.

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Figure legends

Figure 1: An integrated and comprehensive view of activity and inactivity. Adapted from:

http://www.sedentarybehaviour.org/what-is-sedentary-behaviour/[53]

Figure 2: Physical activity and sedentary behaviour of people with COPD. Adapted from:

Pitta, F. et al. 2005[31].

Table 1: Definition of key terms[8]

Term	Definition
Physical activity	Any bodily movement produced by skeletal muscles that results in energy expenditure above resting levels. Physical activity broadly encompasses exercise, sports, and physical activities done as part of daily living, occupation, leisure, and active transportation.
Light physical activity	Activity with a relative intensity of 20 to <40% of VO_{2max}. For the general population, it has been defined as activities that have an energy expenditure of >1.5 to 3 METs. It includes activities such as showering and ironing.
Moderate to vigorous physical activity	Activity with a relative intensity of 40 to <60% (moderate) or $\geq$60% (vigorous) of VO_{2max}. For the general population, it has been defined as activities that have an energy expenditure $\geq$ 3 METs. It includes activities such as brisk walk, cycling, walking uphill, rowing and running.
MET	An index of energy expenditure. One MET is equal to an oxygen uptake of 3.5 mL$\cdot$kg$^{-1}\cdot$min^{-1}, which is the rate of energy expenditure while sitting at rest.

Abbreviations: MET – Metabolic equivalent of tasks; VO_{2max} – Maximum rate of oxygen uptake