The importance of physical activity

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Case history: A 69-year-old man with COPD (FEV_1 59% predicted, 6MWD 85% pred) visits the outpatient clinic after 1 week of wearing an activity monitor. The device shows that the patient currently has a physical activity level of 4500 steps per day. Is this patient sufficiently active? Would you coach him towards a higher physical activity level?

Chapter summary: The promotion of a physically active lifestyle is recommended for all patients with COPD, based on a large evidence base of the health benefits of being physically active. The available physical activity recommendations differ considerably. It has been demonstrated that these differences have a significant impact on the classification of patients with COPD into categories of sufficient and insufficient physical activity. Functional capacity and functional reserve become increasingly limited with progressing disease severity. This makes it difficult for many patients to achieve at least moderate intensity in the Q1
recommendations based on time of physical activity. Preventing sedentary time might be a Q2
relevant and more realistic treatment goal in these patients. Objective measures are available to measure physical activity and their characteristics make these tools suitable for use in clinical practice. Treatment approaches to modify physical activity have gained popularity in recent years. Self-monitoring of daily activities and goal setting with feedback from a pedometer are common elements in these interventions, which have the potential to improve health in patients with COPD.

Physical inactivity is thought to play a crucial role in the development of COPD Q3
comorbidities (*e.g.* osteoporosis, anxiety and depression, diabetes, cancer, muscle Q4
weakness, and cardiovascular disease) [1]. Promotion of a physically active lifestyle has been recommended as part of the non-pharmacological treatment of all patients with COPD, mainly based on the large evidence base of benefits of being physically active that exists in the general population [2, 3]. Prospective epidemiological studies have demonstrated that the risk of all-cause mortality is lower in physically active adults than in their inactive counterparts [4], and that a mid-life increase in physical activity reduces the risk of all-cause mortality [5].

The field of research regarding physical activity in patients with COPD has increased exponentially in the last decade. This growing interest is based on data showing the differences in physical activity behaviour between patients with COPD and healthy,

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age-matched controls [6]. In a systematic review that summarised 11 studies investigating physical activity in patients with COPD, a significant decrease in the duration and intensity of physical activity was observed, with intensity being less affected than duration (75% and 57%, respectively, of values observed in healthy controls) [7]. These results were confirmed in a recent, large cohort study [8]. In the study, patients with COPD presented with a reduction in time spent in low or moderately intense activities in comparison with their healthy counterparts [8]. The physical activity level of patients has been shown to drop dramatically during and after a hospitalisation for an acute exacerbation and is lower in patients with frequent exacerbations [9]. Pitta *et al.* [9] observed markedly lower physical activity values 1 month after hospital discharge when compared with physical activity levels in stable patients with COPD. In comparison with other chronic diseases, such as diabetes and rheumatoid arthritis, the prevalence of inactive patients is significantly higher in COPD [10].

The decrease in physical activity is already present early in the disease [11], and worsens **Q5**
with progressing disease severity [12]. Even (ex-)smokers unaware of their airflow limitation show reductions in physical activity when compared with (ex-)smokers without airflow limitation [13]. The potential mechanisms explaining the presence of (early) physical inactivity and worsening throughout the course of the disease are illustrated in figure 1. Abnormalities in pulmonary function and gas exchange (leading to higher ventilatory requirements during exercise), as well as skeletal muscle dysfunction are already present to a variable degree in early disease stages and can contribute to the perception of increased exertional dyspnoea and leg fatigue [11, 15, 16]. These symptoms make exercise an unpleasant experience and patients probably adapt to this by decreasing their physical activity, most likely beginning with nonessential leisure activities followed by activities of daily living. This results in an inactive lifestyle, which is likely to aggravate exercise limitation [12, 15]. Deconditioning and muscle weakness are physiological consequences of inactivity that can also be observed in healthy subjects within 2 weeks of reduced physical activity [17]. These data suggest that reductions in physical activity will lead to deconditioning, worsening of dyspnoea and a further reduction in physical activity levels [12, 15]. This brings patients into a vicious cycle of inactivity that is difficult to reverse [15].

In addition to reductions in physical activity, impaired exercise capacity is also common in patients with COPD [18]. Although functional capacity is correlated with physical activity,

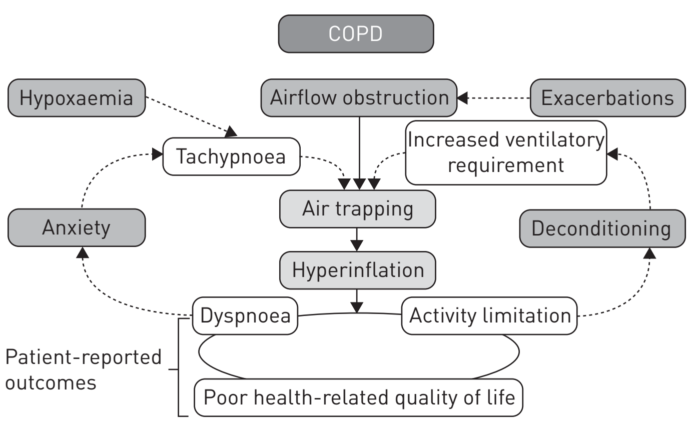

Figure 1. Vicious cycle of symptoms and inactivity. Reproduced and modified from [14] with permission from the publisher.

both present different entities and it is important to make the distinction between both outcomes, as explained in a theoretical framework by Leidy [19] and shown in figure 2.

Functional capacity is defined as the maximum potential to perform activities that people might engage in during the normal course of their lives to meet basic needs, fulfil usual roles, and maintain health and well-being [20]. Functional performance (physical activity) is defined as all activities people actually do in the normal course of their lives (including activities for personal bodily needs like dressing and eating, hobbies, visiting friends, and psychological and spiritual activities). In the remainder of this chapter, the term physical activity will be used as a synonym for functional performance. Functional reserve is the difference between capacity and performance. The closer to functional capacity one is performing activities, the more exertion is required to complete these activities. Increasing one's capacity implies that the performance can be reached with less exertion than before. Engagement in daily physical activity is partially the outcome of an individual choice, especially in subjects with preserved functional capacity. In individuals with more limited functional capacity, this freedom of choice may be restricted, as illustrated in figure 3 [6, 19].

In summary, a distinction should be made between two different concepts: functional capacity, indicating what a patient is capable of doing; and physical activity (functional performance), reflecting what a patient is actually doing.

Definitions

The World Health Organization (WHO) defines physical activity (functional performance) as: "any bodily movement produced by skeletal muscles resulting in energy expenditure" [21]. Exercise is defined as a subset of physical activity that is planned, structured, repetitive and has the aim of improving or maintaining physical fitness [22]. Physical activity also **Q6**

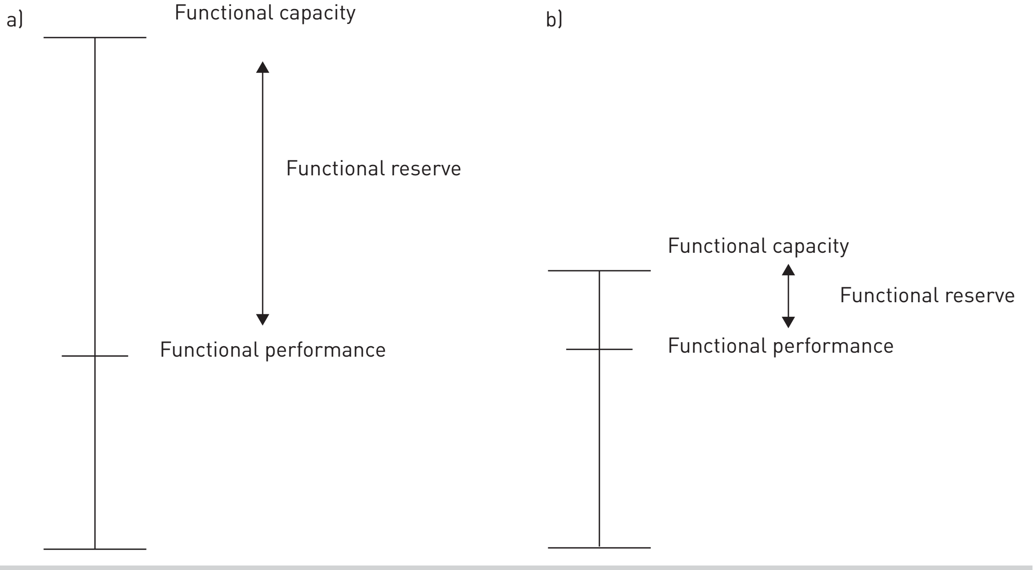

Figure 2. Schematic representation of the relationships between functional capacity, functional performance and functional reserve in a) healthy subjects and b) patients with severe COPD. Reproduced and modified from [19] with permission from the publisher.

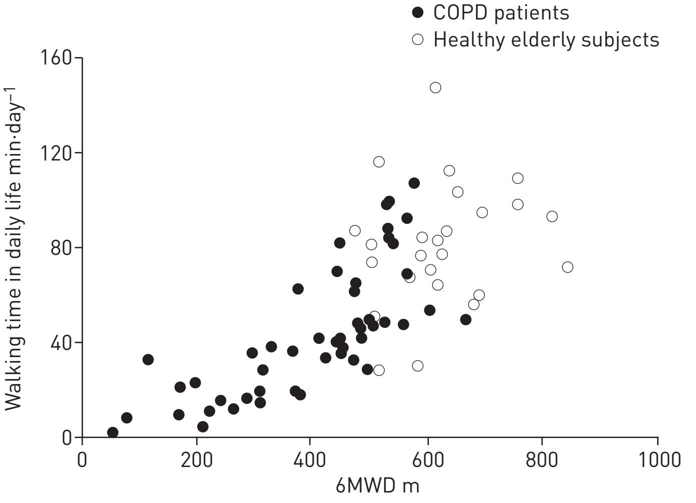

Figure 3. Plot of 6MWD and walking time in daily life assessed during 12 h·day^{-1} in patients with COPD (n=50) and healthy elderly subjects (n=25). It is apparent that in patients with COPD, who have a more limited functional capacity (6MWD), physical activity (performance) and 6MWD (capacity) are more closely related (R^2=0.56; p<0.0001) than in healthy elderly subjects whose capacity is better preserved. In the group with larger functional reserve, the scatter widens and the relationship between the two variables becomes less strong (R^2=0.07; p=0.3). Reproduced and modified from [6] with permission from the publisher.

comprises other components besides exercise, such as domestic and occupational tasks, and basic, everyday tasks required for self-care and independent living.

Physical activity is often classified in activities of light, moderate, vigorous or very vigorous intensity, based on the energy expenditure of the performed activity. Often, classifications are based on the metabolic equivalent of the task (MET). One MET represents resting energy expenditure (upright sitting), equal to 3.5 mL oxygen consumption·kg^{-1}·min^{-1}. Energy expenditure of an activity will be expressed relative to the resting oxygen consumption. For example, a task performed with an intensity of 3 MET requires three times the resting energy expenditure. An outcome frequently used in the literature is the time in physical activity of at least moderate intensity (MPA), comprising time in moderate, vigorous and very vigorous intensity, because this variable has been included in physical activity recommendations.

Sedentary behaviour is defined as any waking behaviour characterised by an energy expenditure of <1.5 MET in a sitting or reclining posture [23]. Sedentary behaviour occurs during the waking day, which means sleep is not included in the definition. Common sedentary behaviours are watching television, driving a car and reading.

Recommendations

Physical inactivity is usually defined as a level of physical activity that is below an optimal threshold [24]. This is based on strong evidence relating insufficient levels of physical activity to negative health outcomes in the general population [25]. Individuals are considered sufficiently active if they accumulate 30 min of at least MPA on ⩾5 days every week [26–28]. These 30 min per day should be performed over and above light intense activities performed in the course of daily living, and can be accumulated in bouts of ⩾10 min with maximal 2 min of interruption within one bout [26–29]. The definition of

MPA varies, however, between different guidelines. It has been further demonstrated that differences in the definition of MPA have a significant impact on the classification of patients with COPD as sufficiently or insufficiently physically active [30, 31]. The most commonly used definitions are summarised in table 1.

Functional capacity and functional reserve might become very limited in the elderly or in patients with chronic diseases like COPD. This will make it difficult for these subjects to achieve recommendations based on MPA as defined by absolute MET cut-off values. The American College of Sports Medicine therefore recommends that for these populations, MPA cut-points relative to the capacity of an individual (*e.g.* 40% oxygen uptake ($V'O_2$) reserve or 50% maximal $V'O_2$) could be used to classify activities as moderately active [26, 28]. Although this approach makes intuitive sense, its validity in terms of resulting in health benefits has, to the best of our knowledge, not yet been supported by data.

The differences between absolute and relative recommendations for patients with different degrees of expiratory flow limitation are illustrated in figure 4. Reductions of time spent in MPA according to an absolute 3 MET cut-off follow the same pattern as reductions in functional capacity with progressing disease severity. Patients become severely inactive and only engage in a very limited amount of MPA as defined by an absolute 3 MET cut-off. This is probably caused by the fact that in these patients >3 MET activities have to be performed at a high percentage of their capacity (small functional reserve). This also becomes apparent when the amount of MPA is reported based on a definition using an intensity cut-off relative to capacity (in this case 50% of $V'O_2$ reserve). As functional capacity becomes smaller, these patients perform large parts of their day at >50% of their functional reserve. The observed relationship between higher levels of fatigue and increasing limitations in expiratory flow and functional capacity might also be related to these observations [33]. This is likely to have implications on the ability of these severely limited patients to increase their levels of physical activity, even though they are very sedentary.

While most guidelines provide recommendations based on duration and frequency of performing MPA (defined as either absolute or relative to capacity), there are also step-based recommendations available [26, 32]. Step-based recommendations are based on a total volume of activity (minimal number of steps) that should be accumulated on a daily basis. The absolute threshold for older adults (⩾50 years of age) to be sufficiently active has recently been estimated to be around 7000 steps (table 1). A "step-defined sedentary lifestyle index" of 5000 steps per day has also been suggested [34]. The proposed volume of 7000 Q7 steps is based on an estimated background of 5000 steps·day^{-1} (which may actually be an

Table 1. Physical activity recommendations for health based on absolute, relative or step-based definitions

Recommendation [ref.]	Frequency	Intensity	Duration	Volume
Absolute [26, 27]	⩾5 days·week^{-1}	⩾3 MET	⩾30 min·day^{-1}	
Relative [26, 28]	⩾5 days·week^{-1}	⩾50% $V'O_{2max}$ or ⩾40% $V'O_2$ reserve	⩾30 min·day^{-1}	
Step-based [32]				⩾7000 steps·day^{-1}

MET: metabolic equivalent of the task; $V'O_{2max}$: maximal oxygen uptake; $V'O_2$: oxygen uptake.

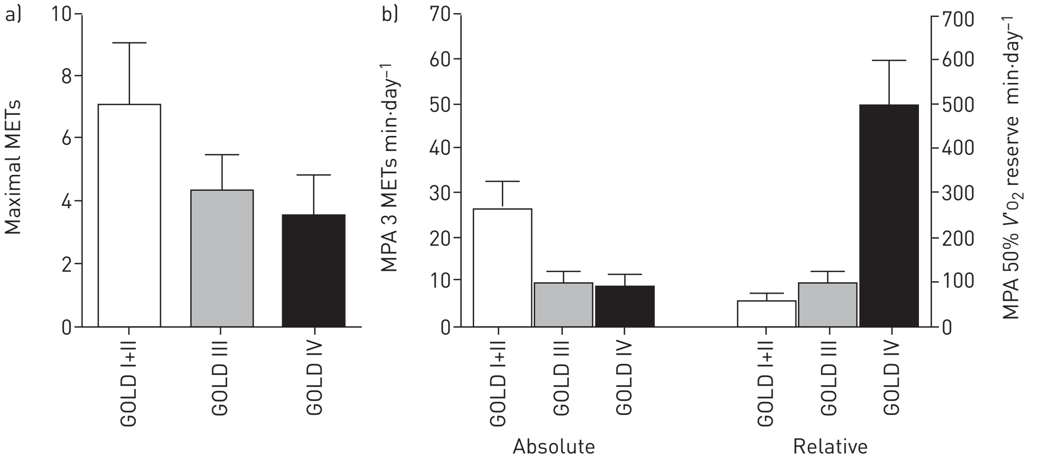

Figure 4. Functional capacity and differences between absolute and relative classifications of moderate physical activity (MPA) in patients with different degrees of expiratory flow limitation. a) The functional capacity of patients in three different Global Initiative for Chronic Obstructive Lung Disease (GOLD) stages. It is apparent that capacity is on average more limited in patients with more severe disease. b) Duration of time spent in MPA (*i.e.* functional performance) based on either absolute or relative definitions. MET: metabolic equivalent of the task; V'_{O_2}: oxygen uptake. Data from [31].

overestimation in older adults and/or special populations (fig. 5)), and an estimated increase to 8000 steps on 5 days including a target of achieving 30 min of MPA (estimated to equal 3000 steps at a cadence of 100 steps per minute) on top of background activities of daily living, which would result in ~7100 steps·day^{-1} averaged over a week [32]. In a similar manner to absolute MET-based recommendations, elderly subjects, or those living with a disability and/or chronic illness might have difficulty achieving these recommendations. These individuals frequently display lower levels of background daily activity (fig. 5), and might not be able to attain step cadences of 100 steps·min^{-1}.

Step-based recommendations relative to the capacity of elderly or frail individuals are not currently available. Most pedometer-based activity interventions base their goals on increases relative to baseline background activity levels (discussed further later). Normative steps per day values for elderly subjects have recently been published [35]. These normative values will facilitate the comparison of measured steps with expected background activity levels in different age groups. Normal average step values do not represent desirable values but rather give an indication of activity levels that are currently being observed in different age groups. While the evidence for step-based guidelines is even less extensive than for MET-based recommendations, this outcome has the advantage that it can be assessed with less advanced measurement equipment (discussed further later).

Physical activity assessment Q8

Self-report

Participation in physical activity can be assessed with questionnaires. However, the practicality of these instruments for individual use in clinical practice is limited. Recall bias, the tendency Q9
to provide socially desirable information (especially of low-intensity and unplanned

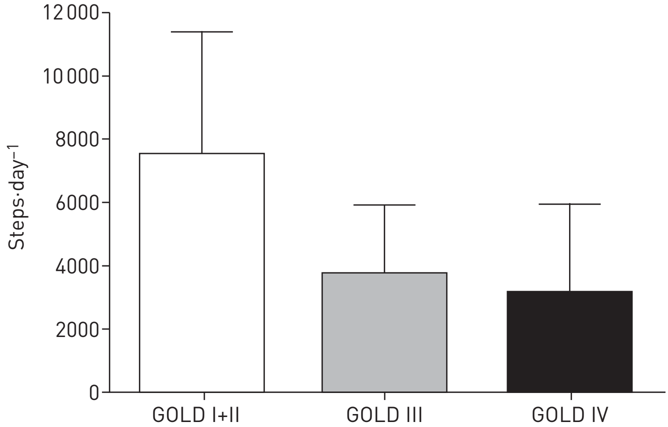

Figure 5. Volume of physical activity presented as mean steps per day in patients with different degrees of airflow limitation. GOLD: Global Initiative for Chronic Obstructive Lung Disease. Data from [31].

"background" activities), and the lack of responsiveness when detecting small changes in physical activity after interventions, are well known limitations to the measurement of physical activity with questionnaires [24, 36–39]. Existing physical activity recall assessments have been estimated to capture no more than 50% of the variance in free-living physical activity levels, and often much less [40]. However, because of the efficiency, utility and low cost of this approach, self-reports of physical activity are often used in large epidemiological studies [24, 37]. In a recent review, it was found that although a total of 15 questionnaires aiming to measure physical activity to some extent had been developed for patients with COPD, none of them was actually based on a conceptual framework, ensuring that the tool would measure concepts relevant to patients [41]. This gap is currently being filled by a project that aims to develop and validate a patient reported outcome measuring physical activity from a patient perspective (www.proactivecopd.com), based on a conceptual framework [42].

Objective measures

Objective measures of physical activity do not rely on information provided by the patient, but instead register biomechanical and/or physiological consequences of performing physical activity [43]. We will focus on accelerometers and pedometers as their small size, low participant burden and relatively low cost make these objective tools suitable for use in clinical practice.

A pedometer is an electronic or electromechanical device worn on the waist or hip that counts each step a person takes by detecting the acceleration of the body's centre of mass during the gait cycle [43]. Steps are registered when the acceleration signal exceeds a critical threshold. The primary limitation of pedometers is that they do not register the intensity of the detected movement. Another limitation of some pedometers might be an underestimation of steps during walking at slow speeds [44–46]. This may limit the usefulness of some devices in patients with severe activity limitation. It might be that some devices perform better than others but each pedometer will need specific validation at walking speeds adopted by patients.

Accelerometry-based motion sensors have become one of the most commonly used methods for assessing physical activity [24, 43]. These devices are commonly worn on the hip, wrist or back and typically sample the acceleration of the body along three axes (tri-axial accelerometers). The acceleration signal is then filtered, rectified and integrated to provide an estimate of physical activity duration and intensity. Accelerometers are sometimes combined with other sensors that register physiological signals, such as heart rate or skin temperature, and are then referred to as combined-activity monitors [24]. These additional signals might improve the estimates of activity intensity, especially during activities that are known to be difficult to assess with pedometers and accelerometers. Activities such as cycling, lifting or carrying objects, and the increased energy cost associated with walking an incline or walking up stairs fall into this category [43].

The validity of objective measures for assessing physical activity in patients with COPD has been the subject of many investigations in recent years [24, 47]. Two studies recently validated six widely used devices against gold standard measurements [48, 49]. The DynaPort MiniMod (McRoberts BV, the Hague, the Netherlands), the Actigraph GT3X (Actigraph, Pensacola, FL, USA) and the SenseWear Armband (BodyMedia, Inc., Pittsburgh, PA, USA) (all employing tri-axial accelerometers) appeared to be sufficiently valid and responsive for use in COPD.

The number of assessment days and hours of use per day are also important factors that **Q10**
may influence the reliability of the physical activity assessment [50, 51]. For cross-sectional analyses, 2–3 days is sufficient for reliable measurement of physical activity in Global Initiative of Chronic Obstructive Lung Disease (GOLD) stage IV patients, whereas up to 5 days of measurement might be required in patients with GOLD stage I [50]. Four measurement days (excluding weekends) were shown to be sufficient to detect changes in physical activity following PR in moderate-to-severe COPD [51].

Health benefits **Q11**

Healthy population

In the healthy population, the benefits of being physically active and the harm of being inactive are well documented [3, 26]. Benefits include a reduction in cardiovascular disease, type 2 diabetes, cancer, dementia, the risk of falling and all-cause mortality [26]. Being physically active preserves bone mass and enhances well-being, quality of life and cognitive function [26]. Interestingly, the protective effects of physical activity on (cardiovascular) morbidity and mortality are independent of the benefits related to physical fitness [52].

Mounting evidence suggests that reducing time in sedentary behaviour may also have important health benefits and, more importantly, these benefits seem to be independent of MPA as defined by absolute cut-offs [53]. In this context, it is important to realise that a person can spend sufficient recommended time in MPA but can still engage in sedentary behaviour for the largest part of the day. An example of such behaviour is seen in elite cyclists, who combine intensive non-weight-bearing exercise with periods of sedentary time (rest, sleep). These subjects were shown to be at high risk of developing osteoporosis [54]. This concept of low-level background activity has been named the “active couch potato” [53]. Besides the total duration of sedentary time, breaks in this behaviour (*e.g.* breaking a sitting behaviour by standing) were shown to have a positive effect on important biomarkers of chronic disease [55]. Accordingly, a more comprehensive view of inactivity has recently been proposed that takes into account the health impacts of physical activity across a spectrum of sedentary to vigorous activity (fig. 6) [53]. **Q12**

COPD patients

In patients with COPD, physical activity has been consistently associated with a reduced risk of hospital admission and mortality [56]. The level of physical activity has been shown to be the most important independent predictor of all-cause mortality in this population. In a large trial of >1400 patients hospitalised for AECOPD, it was observed that physical activity levels at baseline together with dyspnoea and hospital location were significant modifiable predictors of the hospital length of stay [57]. This suggests a direct association between physical activity and the use of health services and related costs. In patients discharged from hospital, those who were less active (objectively measured using an accelerometer) during the week following discharge were more likely to be readmitted within 30 days, independent of the exacerbation history in the preceding year, known to be **Q13** the most important predictor of hospitalisation risk [58]. These results were confirmed in a large trial (>4500 patients) based on self-reported physical activity levels [59].

Several population-based studies investigating the relationship between physical activity and lung function decline demonstrated an inverse relationship [60–64]. This beneficial effect of regular activity seems to be present in active smokers, prior to COPD development, which can be seen as a slower decline in lung function in the more active subjects [65].

Reduced physical activity is associated with greater disease severity (worse lung function) [65, 66], higher levels of dyspnoea [65, 66], lower exercise capacity [67–70] and lower health-related quality of life [66, 71–73], but these conclusions are based on low- to very low-quality research from mostly cross-sectional studies [56]. How being physically active affects balance and bone mineral density is inconsistent in the literature [56]. From recent data collected in a population-based cohort of preclinical patients with COPD ((ex-) smokers unaware of their airflow limitation), it was concluded that inactivity and smoking, rather than the disease COPD as such, were the main risk factors for developing comorbid conditions [74].

Besides the health benefits of being physically active, the direct effects of changing physical activity behaviour are important to notice here, although literature on this is scarce. In a

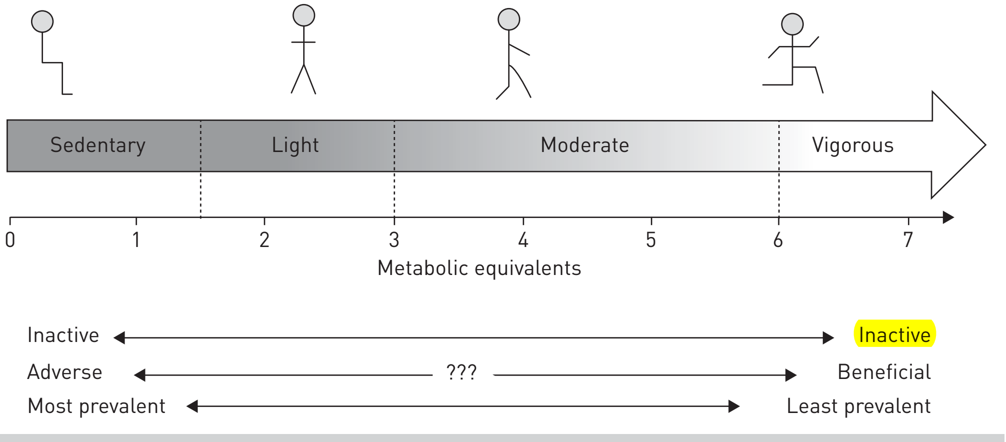

Figure 6. Comprehensive view of health impacts across the full spectrum of physical activity intensity. Reproduced and modified from [53] with permission from the publisher.

recent study, it was observed that patients with COPD who decreased their physical activity levels had an increased mortality risk, but a protective effect of an increase in physical activity on mortality could not be found [75]. Esteban *et al.* [76] showed that patients who changed to a higher level of physical activity or maintained a moderate or high level of physical activity over 2 years of follow-up, showed a decreased rate of exacerbations requiring hospitalisation in the next 3 years. Both studies were based on self-reported physical activity levels.

The consequences of increased sedentary behaviour in patients with COPD, which has already been shown by Pitta *et al.* [6] to be present as an increased sitting and lying time, independent of the MPA level, have not yet been investigated. It might be that decreasing sedentary time is a more relevant and realistic goal for patients with severe COPD, in whom functional reserve is too small to expect an increase in MPA (based on absolute MET cut-offs) is not an achievable goal (fig. 4b). In healthy adults there is a strong negative correlation between sedentary time and time in light-intensity physical activity; individuals who have a positive light–sedentary balance (more time spent in light-intensity physical activity than sedentary time) show cardiometabolic benefits [53]. Although no direct evidence is available, these data suggest that an increase in light-intensity activities, a decrease in total sedentary time and breaking this sedentary behaviour might be relevant treatment goals for patients. **Q14**

Treatment strategies to improve physical activity

In the following section, several treatment options will be discussed that could be used to increase participation in physical activity in patients with COPD. The focus will be both on treatments that mainly aim at increasing functional capacity (*e.g.* supervised exercise training during PR (fig. 2)) and on treatments that aim to specifically modify physical activity behaviour (functional performance (fig. 2)).

Pulmonary rehabilitation

Several studies have investigated the effects of PR upon short- and long-term changes in physical activity, and have found on average only minor changes in physical activity, despite significant improvements in functional capacity [44, 77–86]. From analyses performed in three recent studies, it might even be concluded that the effects of rehabilitation on participation in daily physical activity seem to be largely unrelated to improvements in functional capacity [79, 85, 86]. These results are in line with findings from cardiac and orthopaedic rehabilitation programmes. In these populations, it has also been shown that a high percentage of patients failed to maintain an active lifestyle after acutely increasing their exposure to structured and planned physical activity (*i.e.* supervised exercise training) during a rehabilitation programme [87]. Activities that are more easily integrated into daily life, such as Nordic walking, might be a good alternative or might be used as an adjunct to traditional supervised exercise regimens in selected patients [88]. Widespread acknowledgment of this physical activity-maintenance problem has led to the recognition of daily physical activity as a complex behaviour that probably needs to be targeted with specific interventions. Whether all patients will respond to such interventions is questionable. It is plausible that a minimum amount of functional capacity is needed before physical activity becomes a realistic target for treatment. In addition to functional capacity and symptoms experienced during activity, behavioural and environmental factors have also been shown to be related to participation in daily physical activity in patients with COPD [56].

Modification of patient behaviour

Key components that increase the effectiveness of behavioural interventions targeting physical activity in populations other than COPD have already been summarised in several meta-analyses and international guidelines [87, 89–94]. Greater effectiveness of interventions to change physical activity behaviour has been shown to be causally linked to mobilising social support and the use of well-described/well-established behaviour-change techniques [90]. These established techniques include self-monitoring, stimulus control, problem solving, relapse prevention management, goal setting, self-reinforcement and developing action plans [89, 90, 92]. Larger improvements were associated (in correlational analyses and non-randomised comparisons) with using a cluster of self-regulatory techniques (goal-setting, self-monitoring, providing feedback on performance, goal review) and providing a higher contact time or frequency of contacts [90]. It has also been suggested that we should assess not only the actual behaviour (*i.e.* participation in daily physical activity) but also the readiness/motivation to change in order to apply interventions according to stages of readiness [90]. Motivational interviewing techniques have been recommended as a collaborative communication approach that seems to have a greater effect than the traditional directive communication between the healthcare provider and the patient [90]. These findings are consistent with recent guidelines from the American Heart Association (AHA) on the prevention of heart disease, which recommend the use of motivational interviewing as well as goal-setting, self-monitoring and a high contact frequency in interventions to promote regular physical activity [95]. In a systematic review in 2012, which investigated the effectiveness of activity monitor-based counselling programmes in patients with chronic diseases, evidence of a beneficial effect in patients with diabetes mellitus type 2 and a lack of data in patients with heart failure and COPD was reported [96].

Wearable monitors that provide feedback to users have been used in numerous physical activity research projects in different sedentary adult populations. A meta-analysis of these studies dating from 2007 showed that home-based pedometer walking programmes are successful in getting inactive people to walk ~2000 steps (30%) more per day over their baseline levels [97]. Only one of the studies included in this meta-analysis investigated the effects of lifestyle physical activity counselling with pedometer feedback in patients with COPD [77]. DE BLOK *et al.* [77] found a 1000-step difference in increasing daily activity by adding a physical activity counselling programme to a 9-week PR programme, in comparison with a control group. More recently, the effects of pedometer-based programmes in patients with COPD have been investigated in more detail and increases in daily physical activity ranging 600–3000 steps have been reported in comparison with control groups [98–103]. Two studies reported a pedometer-based intervention, during which patients were coached by telephone [101, 102]. KOVELIS *et al.* [104] found large and statistically significant effects on daily activity (+3000 daily steps) of a 4-week pedometer feedback intervention in inactive smokers. MOY *et al.* [105] reported a significant increase of 1300 steps per day that was induced by a 3-month website-based counselling programme with pedometer feedback in patients with COPD.

A different approach was taken by PLEGUEZUELOS *et al.* [106], who tried to manipulate environmental factors by implementing urban walking circuits. Implementation of walking circuits in patients with COPD resulted in an increase in physical activity of 30 min per day in comparison to a control group after 9 months of follow-up, as assessed by self-report [106]. Creating a healthy and safe environment for physical activities might be a crucial prerequisite for individuals to become more active. This is also promoted by an initiative of the WHO, **Q15**
called Healthy Cities [107].

In summary, strategies to modify physical activity behaviour are gaining popularity in the COPD population and these interventions seem to have the potential to increase participation in physical activity. Overall, however, the evidence base is limited and studies involve small samples. Often, programme content has not been clearly defined, but self-monitoring of daily activities and goal setting based on relative increases in baseline background activity with pedometer feedback, were common elements in most of these studies. Wearable devices created by several large technology companies are gaining popularity and are marketed to promote health behaviour change. It is important to stress that while these devices have the potential to facilitate behaviour change, the success of interventions will depend on engagement strategies that are built around these tools rather than on the technology itself [108]. **Q16**

Conclusion

Promotion of a physically active lifestyle has been recommended as part of the non-pharmacological treatment of all patients with COPD, based on a significant body of evidence on the benefits of being physically active that exists both in the general population and in patients. A distinction should be made between functional capacity, indicating what a patient is capable of doing, and actual functional performance (*i.e.* physical activity), reflecting what a patient is actually doing in daily life. Available physical activity recommendations differ from each other regarding the definition of MPA, and it has been demonstrated that these differences have a significant impact on the classification of patients with COPD into sufficiently or insufficiently physically active groups. Functional capacity and functional reserve become increasingly limited with progressing disease severity. This will make it difficult for many patients to achieve recommendations based on time in physical activity of at least moderate intensity, as defined by absolute MET cut-off values. Objective measures of physical activity (accelerometers and pedometers) are available and their characteristics make these objective tools suitable for use in clinical practice. Although no direct evidence is available, it might be that decreasing sedentary time is a relevant and realistic goal for patients with (severe) COPD. Strategies to modify physical activity behaviour have gained popularity in recent years. Self-monitoring of daily activities and goal setting based on relative increases in baseline background activity with feedback of a pedometer were common elements in most of the available studies. These interventions have the potential to increase participation in physical activity and improve health in patients with COPD.

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Author Queries

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Q1 Chapter summary, "This makes it difficult…" I have reworded this sentence slightly. Please check that the intended meaning remains, rewording as necessary.

Q2 Chapter summary, "Preventing sedentary time…" Should this be changed to "Reducing sedentary time…"?

Q3 As the ERS Monograph is a book, we try to ensure that information that is more relevant to the general topic of the book is not repeated within the chapters themselves but is only given in the book's overall Introduction. At the Guest Editors' recommendation, I have therefore removed the first two sentences of your chapter and reworded the third sentence. I hope this is acceptable. I have also renumbered all subsequent references. Please check that all references have been renumbered correctly.

Q4 A list of abbreviations that are commonly used in this book will be printed at the front of the Monograph. Some of the abbreviated terms in this chapter have therefore been presented without expansion in the first instance.

Q5 References. It is our house style to cite references in numerical order. Where references are cited in figures and tables, their first citation is where the figure/table is cited in the text and not where the figure/table appears on the page. I have therefore renumbered the references. Please check that this has been done correctly.

Q6 I have added in references for the definitions of functional capacity and physical activity. Please check and confirm that the references provided are correct. If necessary, please provide references for the definitions of functional performance and functional reserve.

Q7 "The proposed volume of 7000…" This sentence sounds incomplete. Please check that it is correct, rewording as necessary.

Q8 Physical activity assessment. I have added subheadings into this section. Please check and confirm that this has been done correctly.

Q9 "Recall bias…". I have reworded this sentence slightly. Please check that the intended meaning remains, rewording the sentence as necessary.

Q10 "The number of assessment days…" As I have added subheadings to this section, should a subheading be added before this paragraph? If so, please suggest a subheading.

Q11 Health benefits. I have added subheadings into this section. Please check and confirm that this has been done correctly.

Q12 "Accordingly, a more comprehensive view…" As figure 6 is reproduced from reference [53], I have added a citation to this reference to the sentence. I hope that is acceptable.

Q13 "In patients discharged from hospital…" Can this sentence be reworded as follows: "In patients discharged from hospital, those who were less active (objectively measured using an accelerometer) during the week following discharge were more likely to be readmitted within 30 days, independent of the exacerbation history in the preceding year; this was known to be the most important predictor of hospitalisation risk [55]." If not, please clarify what is meant here, rewording as necessary.

Q14 "It might be that…" Can this sentence be reworded as "It may be that decreasing sedentary time is a more relevant and realistic goal for patients with severe COPD, in whom functional reserve is too small to expect an increase in MPA (based on absolute MET cut-offs) (fig. 4b)."? If not, please clarify exactly what is meant here, rewording as necessary.

Q15 "Creating a health and safe…" I have reworded this sentence slightly. Please check and confirm that the intended meaning remains, rewording as necessary.

Q16 Should a further subheading be added to the Treatment Strategies section, just before the paragraph that begins "In summary…"? Please provide a subheading as you feel necessary.