ORIGINAL RESEARCH

Seasonal variations in objectively assessed physical activity among people with COPD in two Nordic countries and Australia: a cross-sectional study

Hanne Hoaas[1,2], Paolo Zanaboni[1], Audhild Hjalmarsen[3,4], Bente Morseth[5], Birthe Dinesen[6], Angela T. Burge[7,8,9], Narelle S. Cox[7,9], and Anne E. Holland[7,8,9]

[1] Norwegian Centre for E-health Research, University Hospital of North Norway, Tromsø, Norway
[2] Faculty of Health Sciences, UiT The Arctic University of Norway, Tromsø, Norway
[3] Department of Clinical Medicine, UiT The Arctic University of Norway, Tromsø, Norway
[4] Department of Pulmonary Medicine, University Hospital of North Norway, Tromsø, Norway
[5] School of Sport Sciences, UiT The Arctic University of Norway, Tromsø, Norway
[6] Laboratory of Welfare Technologies – Telehealth & Telerehabilitation, SMI, Department of Health Science and Technology, Aalborg University, Aalborg, Denmark
[7] La Trobe University, Melbourne, Australia
[8] Alfred Health, Melbourne, Australia
[9] Institute for Breathing and Sleep, Melbourne, Australia

Abstract

Purpose:

Seasons and weather conditions might influence participation in physical activity and contribute to differences between countries. This study aimed at investigating whether there were differences in physical activity levels between Norwegian, Danish and Australian people with chronic obstructive pulmonary disease (COPD), and establishing if any variations in physical activity were attributable to seasons.

Patients and methods:

Study subjects were people with COPD who participated in two separate clinical trials: the iTrain study (Norway, Denmark, and Australia) and the HomeBase study (Australia). Physical activity was objectively assessed with an activity monitor; variables were total energy expenditure, number of daily steps, awake sedentary time, light, and moderate-to-vigorous intensity physical activity. Differences in physical activity between countries and seasons were compared, with adjustment for disease severity.

Results:

In total, 168 participants were included. After controlling for disease severity, awake sedentary time was greater in Danish participants compared to the other countries (median 784 min/day [660-952] vs 775 min/day [626-877] for Norwegians vs 703 min/day [613-802] for Australians, p=0.013), whilst time spent in moderate to vigorous physical activity was lower (median 21 min/day [4-73] vs 30 min/day [7-93] for Norwegians vs 48 min/day [19-98] for Australians, p=0.024). Participants tended to walk more during summer (median 3502 [1253-5407] steps/day) than in spring (median 2698 [1613-5207] steps/day), winter (median 2373 [1145-4206] steps/day) and autumn (median 1603 [738-4040] steps/day), regardless of geography. The median difference between summer and other seasons exceeded the minimal clinically important difference of 600 steps/day. However, the differences were not statistically significant (p=0.101).

Conclusion:

Seasonal variations may influence physical activity outcomes over time, irrespective of any interventions delivered. Understanding differences in physical activity patterns and seasonal variations across countries will assist in interpreting data from multi-national trials as well as health registries where physical activity is an outcome.

Keywords: Chronic obstructive pulmonary disease; activity monitoring; population comparison; seasons; weather

Introduction

Physical inactivity contributes significantly to morbidity and mortality worldwide.[1] People with chronic obstructive pulmonary disease (COPD) are less physically active than healthy age-matched controls,[2,3] and physical inactivity and sedentary behavior are associated with an increased risk of all-cause mortality in this group.[4-7] Inactivity is also thought to lead to a more rapid progression of COPD and the development of comorbidities in these individuals.[4-6,8] Conversely, disease progression and comorbidities may also lead to decreased physical activity. Given the interplay between physical activity and health in this group,[9] a physically active lifestyle is recommended for all individuals with COPD.[10]

In healthy people, physical inactivity varies between countries, with populations from high-income countries being the most inactive.[11] Socio-economic factors may also have some influence on physical activity among people with COPD. In a study comparing physical activity levels among people with COPD with different socio-economic and ethnic characteristics, the percentage of Austrians performing less than 30 minutes of moderate to vigorous physical activity per day was 48% compared with 23% in a disease severity-matched Brazilian group.[12]

Seasonal variations in terms of duration of daylight time and weather conditions might also affect physical activity levels and could be a confounder when investigating physical activity in COPD.[13-16] Winter months with cold temperatures have an impact on lung function and the risk of exacerbations.[17,18] In a study of 190 people with COPD in Canada, temperature was positively related to the number of steps per day, while precipitation was negatively related.[16] However, extremes of hot weather have also been linked to increased morbidity among those with COPD.[18]

The objectives of this study were: 1) to investigate whether there were differences in physical activity levels between Norwegian, Danish and Australian people with COPD and 2) to establish if any variation in physical activity levels was attributable to seasons (winter, spring, summer, autumn). Understanding differences in physical activity patterns and seasonal variations in physical activity across countries will assist in interpreting data from multi-national trials as well as health registries where physical activity is an outcome.

Material and methods

Study subjects and design

Study subjects were participants in two separate clinical trials, the iTrain study and the HomeBase study. Baseline data were used for this analysis. The iTrain study was an international multi-center randomized controlled trial on telerehabilitation for people with COPD in Norway, Denmark and Australia.[19] The HomeBase study was a randomized controlled trial investigating home-based pulmonary rehabilitation for people with COPD in Australia.[20] Common inclusion criteria for both trials were a confirmed diagnosis of COPD (forced expiratory volume in 1 second over forced vital capacity ratio/ forced vital capacity (FEV_1/FVC) ≤ 0.70) and age between 40 and 80 years. Participants in these trials were recruited during all seasons. Participants in the HomeBase study were recruited between March 2013 to March 2014. Physical activity was measured in a subgroup of participants recruited from the time when additional funding became available until the end of the trial. The iTrain study recruited from October 2014 to December 2016. The current study included physical activity data in a subgroup of participants recruited from the beginning of the trial to August 2016 when data analysis was initiated.

Settings

The Tromsø area where the Norwegian participants lived has a humid subarctic continental climate with cool summers and snowy winters. The temperature typically varies from -7°C to 15°C over the course of a year, and is rarely below -13°C or above 21°C. The warm season lasts from June 14 to September 3 with an average daily high temperature above 12°C. The warmest month of the year is July. The cold season lasts from November 16 to March 31 with an average daily high temperature below 1°C. The coldest month of the year is February.[21]

The Danish participants lived in the area near Esbjerg, which has a mild humid temperate climate characterized by warm summers. Over the course of a year, the temperature typically varies from -2°C to 21°C and is rarely below -8°C or above 26°C. The warm season lasts from May 27 to September 10 with an average daily high temperature above 18°C. The warmest month of the year is

July. The cold season lasts from December 4 to March 5 with an average daily high temperature below 6°C. The coldest month of the year is February.[22]

The area around Melbourne, where the Australian participants were situated, also has a mild humid temperate climate with warm summers and no dry season. The temperature typically varies from 6°C to 26°C over the course of a year and is rarely below 3°C or above 34°C. The warm season lasts from December 20 to March 14 with an average daily high temperature above 24°C. The warmest month of the year is January. The cold season lasts from May 22 to September 3 with an average daily high temperature below 15°C. The coldest month of the year is July.[23]

Data collection and analysis

Data on participant characteristics included nationality, gender, age, body mass index (BMI), number of comorbidities, smoking history, lung function measured by spirometry, disease severity (I to IV) according to the former staging system of the Global Initiative for Chronic Obstructive Lung Disease (GOLD),[10] use of long-term oxygen therapy (LTOT), dyspnea measured with the modified Medical Research Council dyspnea scale (MMRC),[24] and functional walking capacity measured by the 6-minute walk distance (6MWD).[25]

Physical activity levels were objectively assessed at baseline, prior to any implementation of interventions, with an activity monitor (SenseWear Armband, BodyMedia, Pittsburgh USA). Participants were asked to wear the activity monitor continuously for seven consecutive days, except for personal hygiene or other water-based activities. Minute-by-minute output was exported using SenseWear Professional version 8.0 software (BodyMedia, Inc). The first and the last day of recording were excluded from analysis to avoid incomplete measurements which could introduce a bias. Samples without at least one weekend day or without 5 valid days with wear time ≥12 hours days were excluded.[13,26] All valid days were included in the analysis. Physical activity outcomes were measured total energy expenditure in kilojoules (kJ) per day, total number of steps per day, minutes of awake sedentary time per day, total minutes of light intensity physical activity per day (LIPA), total minutes of moderate-to-vigorous physical activity (MVPA) per day, and total minutes in ≥10 minutes bouts of moderate-to-vigorous physical activity (MVPA bouts). Awake sedentary time was defined as activity where the metabolic equivalent was ≤1.5 METs, and measured sleep was excluded.[26] Non-wear time was not included in measurement of sedentary behavior. Any activity between 1.5 and 3 METs was defined as LIPA, and activity measured to ≥3 METs was considered MVPA.[27]

Differences in physical activity levels were compared across the three countries (Norway, Denmark and Australia). Seasonal variations were defined according to the meteorological seasons in the Northern Hemisphere and the Southern Hemisphere. The four seasons were defined as follows: winter (from December 1 to February 28 in Norway and Denmark, from June 1 to August 31 in Australia), spring (from March 1 to May 31 in Norway and Denmark, from September 1 to November 30 in Australia), summer (from June 1 to August 31 in Norway and Denmark, from December 1 to February 28 in Australia), and autumn (from September 1 to November 30 in Norway and Denmark, from March 1 to May 31 in Australia).

Statistical analyses

Descriptive data were reported as median and interquartile range (IQR) for continuous variables, and counts and percentages for categorical variables. Normality of distribution was tested with the Kolmogorov-Smirnov test. Differences in participant characteristics between the three countries were compared with Kruskal-Wallis test for continuous variables and chi-squared test for categorical variables. A Mann-Whitney test was used as a post-hoc test to discover which specific means differed when the overall Kruskal-Wallis result was significant. Log transformation (used for energy expenditure) and cubic root transformation (used for steps, LIPA and MVPA time) were applied to the physical activity variables with a non-parametric distribution in order to obtain normally distributed data so that parametric methods for statistical analyses could be performed. No transformation nor statistical analyses were applied to time in MVPA bouts due to the high number of zero values. Values reported in tables are original median and IQR values. Differences in physical activity variables between countries and seasons were compared with one-way ANOVA. A Tukey post-hoc test was used to discover which specific means differed where the overall ANOVA result was significant. Between country differences were also adjusted for disease severity (FEV_1 %) using one-way ANCOVA. The combined effect of seasons and countries on physical activity was analyzed with two-way ANOVA. A p-value <0.05 was considered significant for all tests. All statistical analyses were performed with IBM SPSS Statistics Version 25.

Results

Participant characteristics

In total, 168 participants with moderate to severe COPD from Norway, Denmark and Australia were included (Table 1). The Australian sample consisted of 61 participants from the HomeBase study and 33 participants from the iTrain study, while samples for Norway (n=38) and Denmark (n=36) consisted only of participants from the iTrain study. Demographics for the three groups were generally similar, although the percentage of participants in GOLD stage III and IV (severe and very severe airflow limitation) was higher among the Danish participants. Australian participants had the highest number of comorbidities and Danish participants had a lower functional walking capacity.

Table 1 Characteristics of participants with COPD from Norway, Denmark and Australia

	Norway (n=38)	**Denmark (n=36)**	**Australia (n=94)**	**p-value**	**Post-hoc***
Sex,					
male	24 (63%)	20 (55%)	52 (55%)	0.696	
Age, year	66 [63-72]	63 [61-68]	66 [60-73]	0.211	
BMI, kg/m^2	28.4 [24.0-33.1]	25.6 [22.9-28.0]	26.0 [22.0-30.5]	0.066	
Comorbidities, number	2 [1-3]	2 [0-2]	3 [2-4]	<0.001	A vs N = 0.009
					D vs A = 0.001
Smoking status				0.085	
Current smoker	14 (37%)	13 (36%)	18 (19%)		
Ex smoker	24 (63%)	23 (64%)	73 (78%)		
Never smoked	0 (0%)	0 (0%)	3 (3%)		
Smoking, pack years	24 [15-40]	40 [25-46]	45 [31-56]	<0.001	D vs N = 0.003
					A vs N = 0.001
FEV_1/FVC	52.8 [44.0-59.0]	51.5 [43.0-62.5]	43.5 [34.0-56.0]	0.002	A vs N = 0.008
					D vs A = 0.002
FEV_1, liters	1.32 [0.97-1.82]	0.92 [0.69-1.11]	1.13 [0.86-1.50]	<0.001	D vs N = 0.001
					D vs A = 0.002
FEV_1, % predicted	50.7 [38.7-63.8]	32.5 [25.0-41.0]	44.0 [32.0-62.0]	<0.001	D vs N = 0.001
					D vs A = 0.001

FVC, % predicted	74.7 [67.0-90.0]	65.5 [48.5-78.0]	74.0 [62.0-90.0]	0.011	D vs N = 0.013 D vs A = 0.004
Disease severity					
GOLD II	20 (53%)	3 (8%)	40 (43%)	<0.001	
GOLD IIII	11 (29%)	15 (42%)	38 (40%)		
GOLD IV	7 (18%)	18 (50%)	16 (17%)		
Use of LTOT, yes	5 (13%)	9 (25%)	12 (13%)	0.204	
MMRC				0.642	
Score 0	2 (5%)	2 (6%)	1 (1%)		
Score 1	11 (29%)	10 (28%)	40 (43%)		
Score 2	12 (32%)	13 (36%)	27 (29%)		
Score 3	11 (29%)	10 (28%)	23 (24%)		
Score 4	2 (5%)	1 (3%)	3 (3%)		
6MWD, meters	416 [350-480]	318 [193-383]	427 [358-480]	<0.001	D vs N = 0.001 D vs A = 0.001
Lowest SpO2 during 6MWD, %	90 [86-93]	90 [86-92]	90 [86-93]	0.978	
Max HR during 6MWD, beat per minute	112 [99-127]	115 [106-122]	113 [102-122]	0.889	
SOB end of 6MWD, Borg CR-10 scale	5 [4-7]	3 [2-3]	4 [3-5]	<0.001	D vs N = 0.001 D vs A = 0.002
RPE end of 6MWD, Borg CR-10 scale**	4 [2-6]	3 [2-4]	3 [2-5]	0.432	
Gait aid, yes	2 (5%)	6 (17%)	8 (9%)	0.218	

Data are median [interquartile range] for continuous variables, counts and percentages for categorical variables. BMI = body mass index; FEV_1 = Forced expiratory volume in the first second; FVC = Forced vital capacity; LTOT= long-term oxygen therapy; MMRC = Modified version of the Medical Research Council Scale; 6MWD = 6-minutes walking distance; SpO2 = Peripheral capillary oxygen saturation; HR = Heart rate; SOB = Rating of perceived shortness of breath; RPE = Rating of perceived exertion for leg fatigue.

*=Only significant comparisons are listed.

**= For the Australian participants, this variable was only calculated for the 33 participants in the iTrain study.

Differences in physical activity levels across countries

All subjects had valid physical activity measurements from 5 days including 1 weekend day with recordings of ≥12 hours per day. There was a statistically significant difference in wear time between all countries (p=0.001). Danish participants wore the activity monitor the most. Physical activity levels were higher for Norwegian and Australian participants compared to Danish participants (Table 2). Danish participants had a lower number of daily steps, less time spent in MVPA, and more awake sedentary time compared to the Australians (p=0.025, 0.014 and 0.007, respectively). After controlling for FEV_1, differences in time spent in MVPA and awake sedentary time across countries persisted (p=0.024 and 0.013, respectively), while the difference for daily number of steps was no longer statistically significant.

Table 2 Physical activity among participants from Norway, Denmark and Australia

	Norway (n=38)	**Denmark (n=36)**	**Australia (n=94)**	**p-value**	**Post-hoc**	**p-value after controlling for FEV_1**
Wear time, min/day	1361 [1340-1414]	1429 [1408-1437]	1418 [1401-1429]	0.001	D vs N&A N vs A	
Energy expenditure, kJ/day	9790 [8237-11754]	8439 [7772-9641]	8320 [7569-10843]	0.266		0.288
Steps, number/day	1672 [1020-3839]	1534 [778-3194]	2916 [1316-4986]	0.025	D vs A	0.133
Awake sedentary time, min/day	775 [626-877]	784 [660-952]	703 [613-802]	0.010	D vs A	0.013
Total LIPA, min/day *	158 [81-219]	178 [124-234]	208 [132-249]	0.388		0.422
Total MVPA, min/day	30 [7-93]	21 [4-73]	48 [19-98]	0.014	D vs A	0.024
Time in MVPA bouts, min/day	8 [0-30]	4 [0-26]	7 [0-24]	n.a		n.a

Data are median [interquartile range]. kJ = Kilojoules; LIPA= Light-intensity physical activity; MVPA= Moderate-to-vigorous physical activity; min= minutes. n.a= non applicable. D vs N&A, N vs A and D vs A = p-value ≤0.050, only significant comparisons are listed.
* LIPA for the Australian sample was available for the 33 participants in the iTrain study only.

Effect of seasonal variations on physical activity levels

The median (IQR) number of steps for all patients tended to be highest in summer (3502 [1253-5407] steps/day) with lower levels in spring (2698 [1613-5207] steps/day), winter (2373 [1145-4206] steps/day) and autumn (1603 [738-4040] steps/day). The difference between summer and other seasons exceeded the minimal clinically important difference of 600 steps/day.[28] However, there was no statistically significant difference among seasons (p=0.101). The same tendency described for steps could be seen for the total MVPA time. Nevertheless, there were no statistically significant difference among seasons for any of the physical activity variables (Table 3).

Table 3 Physical activity in the different seasons

	Winter n=50 (NO=12;DK=8; AU=30)	**Spring n=40** (NO=11;DK=8; AU=21)	**Summer n=22** (NO=0;DK=4; AU=18)	**Autumn n=56** (NO=15;DK=16; AU=25)	**p-value**
Energy expenditure, kJ/day	9075 [7796-10297]	8571 [7748-11783]	8491 [7642-11164]	8442 [7261-10314]	0.181
Steps, number/day	2373 [1145-4206]	2698 [1613-5207]	3502 [1253-5407]	1603 [738-4040]	0.101
Awake sedentary time, min/day	721 [608-868]	755 [635-901]	700 [617-801]	735 [620-824]	0.796
Sleep time, min/day	410 [316-463]	362 [316-451]	365 [317-481]	401 [314-463]	0.982
Total LIPA, min/day *	160 [102-237]	197 [150-255]	159 [99-251]	177 [106-230]	0.487
Total MVPA, min/day	39 [15-88]	38 [20-100]	62 [11-108]	27 [8-90]	0.326
Time in MVPA bouts, min/day	9 [0-23]	7 [0-34]	7 [2-25]	5 [0-25]	n.a

Data are median [interquartile range]. kJ = Kilojoules; LIPA= Light-intensity physical activity; MVPA= Moderate-to-vigorous physical activity; min= minutes; n.a= non applicable; NO= Norway; DK= Denmark; AU= Australia.
* LIPA for the Australian sample was available for the 33 participants in the iTrain study only.

Results from the two-way ANOVA showed that there was no significant effect for the interaction between country and seasons on the number of steps (p=0.432), with no significant main effect for season (p=0.273), but a significant main effect for nationality was confirmed (p=0.018). The interaction effect between seasons and nationality on awake sedentary time was not statistically significant (p=0.774). There was no significant main effect for season (p=0.936), but a significant main effect for nationality was confirmed (p=0.044). The interaction effect between seasons and nationality on MVPA time was not statistically significant (p=0.801). There was no significant main effect for season (p=0.633), but a significant main effect for nationality (p=0.042).

Discussion

This study aimed at investigating whether there were differences in physical activity levels between Norwegian, Danish and Australian people with COPD. The results revealed some differences across countries after controlling for disease severity. Danish participants spent more time in an awake sedentary state and less time in MVPA. The study aimed also at establishing whether variations in physical activity levels were attributable to seasons. Although it did not reach statistical significance, there was a trend for the participants to walk more and with higher intensity during summer when compared to spring, winter and autumn, regardless of geography.

Differences in physical activity levels across countries, as seen in this study, has been observed before. A study on participation in physical activity among Austrian and Brazilian people with COPD, suggested that Brazilian participants, due to lower socio-economic status, may ambulate more for daily activities and to access public transportation than the Austrians who more often had access to their own cars.[12] In our study, the countries involved have similar prosperity indexes and socio-economic standards,[29] while there were differences in disease severity among participants. Disease severity has been shown to have a weak-to-moderate positive association with reduced physical activity in patients with COPD.[5,30] This partially explained the differences in physical activity in the current study, as the Danish participants, who had higher sedentary time and lower MVPA time, also had more severe COPD than their counterparts in Norway and Australia. As disease severity may influence physical activity, it is important to take this into account in clinical studies, and ensure that participants are properly stratified to achieve similarity between groups in multi-center and multi-national trials.

For the healthy population, nationality seems to influence self-reported physical activity more than in people with COPD. According to the Global Observatory for Physical Activity, 53% of the Norwegian population and 76% of the Danish population report being physical active compared with only 43% of the Australian population.[31] However, these findings are based on self-reported data and may not be as accurate as our objectively measured data as large variations between self-reported and accelerometer-measured physical activity and sedentary time have been reported.[32]

In our study, the difference in awake sedentary time and time spent in MVPA persisted across countries after controlling for disease severity. Danish participants, who spent significantly longer periods of the day in sedentary activities and less time walking at higher intensities, had significantly lower functional walking capacity (indicated by 6MWD) than participants from other countries. There is a moderate association between physical activity and physical capacity.[5] In the current study, participants from Norway and Australia had a median walking distance of >400 meters on the 6MWD and achieved ≥30 minutes of MVPA, whereas Danish participants walked a median of <400 meters and did not meet the value of ≥30 minutes of MVPA which is recommended by the American College of Sports Medicine.[33] Such correlation between physical capacity and intensity of physical activity has previous been observed by Pitta et al.[2] However, high physical capacity does not always translate into higher levels of physical activity, as physical activity is also influenced by psychological factors like habit, self-efficacy and health beliefs.[34,35] In addition to individual factors, social and physical environment such as urban planning, transport systems, and parks and trails may explain why some people are more physically active than others.[36] A qualitative study identified barriers and enablers for participation in physical activity among COPD patients after hospital admission due to a disease exacerbation. The main barriers were health-related (comorbidities, COPD symptoms, injury and illness), self-related (advancing age and experience of previous physical activity) and environment-related (weather, transport and finance).[34] Main enablers were identified as access to health professionals and equipment, social support, routine and hobbies, personal goals and motivation, and the feeling of getting better when being more active.[34]

Reducing sedentary time can decrease cardiovascular risk in other patient groups.[37] As many patients with COPD have cardiovascular comorbidities,[38] strategies to reduce sedentary time may be clinically relevant in COPD.[39] Targeting sedentary behavior can also be effective in improving the ability to stand up from a seated position among older adults, thus improving physical functioning.[40] A recent review suggests that future trials should examine sedentary time as an outcome when assessing physical activity interventions as this may have clinical benefits for people with COPD.[39] In the current study, variations in step count across the year were not offset by changes in awake sedentary time, as sedentary time was unchanged all year. Strategies that target sedentary behavior might have a potential for increasing overall physical activity.

Climate and variations in weather conditions following the different seasons may influence levels of daily physical activity in COPD.[5] Studies have reported lower number of steps during rainy and colder days, in winter and during extreme summer heat.[14,16,41,42] A recent study of people with COPD residing in Canada reported that an increase in daytime temperature of 10°C translated into 316 more daily steps (6.6% of mean steps/day) whereas rainfall of 10 mm had a negative effect of 175 less daily steps (3.6% of mean steps/day).[16] The current study was conducted in three countries with climate zones spanning from Arctic climate with cold summers and cold winters to tropical influenced climate with hot summers and mild winters. Participants with COPD tended to walk more during summer than during spring, winter and autumn, regardless of location. Results did not reach statistical significance due to the modest sample size in each group. However, the overall difference between summer (3502 steps/day) and winter (2373 steps/day) exceeded the minimal clinical important difference (between 600 and 1100 steps/day) in daily step count after pulmonary rehabilitation.[28] An improvement of more than 600 steps/day after pulmonary rehabilitation is also reported to reduce the risk of hospitalization in patients with COPD.[28] We therefore consider the difference of 1129 daily steps between summer and winter to be of clinical relevance.

Seasonal differences have implications for clinical trials that measure physical activity over time, as the season in which the measurement is taken may influence outcomes irrespective of any intervention delivered. The effect of temperature and season on daily steps has recently been reported in a 3-months physical activity intervention trial on people with COPD.[43] An increase in daily steps was found in subgroup analysis of both a group receiving a pedometer and web-based support and a group receiving a pedometer intervention alone during the transition from spring to summer. During the transition from summer to autumn, the group with web-based support experienced an increase in daily step count from baseline, while the group using only pedometer had a significant decline.[43] The influence of seasonal variations on physical activity habits may be relevant for both selected patient groups, such as COPD, as well as for the healthy population. Results from multi-national trials as well as health registries where physical activity is an outcome should take into account differences in physical activity patterns due to seasonal variations both if the trial is performed across countries or within one country.

Study strengths and limitations

This study included a total of 168 participants from three countries. Study subjects were participants enrolled in two separate trials using common inclusion criteria, methods and algorithms for objectively measurements of physical activity. This allowed us to investigate differences in physical activity across countries based on a larger sample than that from a single trial. Differences in disease severity between participants in the different countries were found, and as a consequence controlled for. Danish participants wore the activity monitor for longer each day, and by this, they might have recorded longer time in sedentary activities than their counterparts might. The lower number of Nordic patients with physical activity data collected during summer may have influenced the results on seasonal variations. Recruitment during summer was low due to summer holiday for both healthcare personnel supporting the recruitment procedures and potential participants. We recommend that future studies investigating seasonal variation will be attentive to include enough participants in each season. The majority of the physical activity variables in the dataset were characterized by a non-normal distribution. We therefore transformed those variables to achieve normal distribution and use parametric tests. However, similar results were achieved by use of non-parametric tests. These data represent cross sectional observations rather than assessment of the longitudinal impact of seasons on a given individual. Further studies taking into account seasonal effects on changes in physical activity over time are required.

Conclusion

In this study, Norwegian, Danish and Australian people with COPD differed in terms of time spent in awake sedentary and moderate-to-vigorous physical activity after controlling for disease severity. There was a tendency for participants to walk more and with higher intensity during summer than during spring, winter and autumn, regardless of geography. Weather conditions and seasonal variations may influence outcomes in clinical trials and health registries measuring physical activity over time, irrespective any interventions delivered, and should be taken into account when interpreting results.

Abbreviations

BMI = body mass index
COPD = chronic obstructive pulmonary disease
FEV1 = forced expiratory volume in the first second
FVC = forced vital capacity
GOLD = Global initiative for chronic obstructive lung disease
HR = heart rate

kJ = kilojoules

LIPA = light-intensity physical activity

LTOT = long-term oxygen treatment

METs = metabolic equivalent

min = minutes

MMRC = modified Medical Research Council dyspnea scale

MVPA = moderate-to-vigorous intensity physical activity

MVPA bouts = 10 minutes bouts of moderate-to-vigorous intensity physical activity

RPE = rating of perceived exertion for leg fatigue

SOB = rating of perceived shortness of breath

SpO2 = peripheral capillary oxygen saturation

6MWD = 6-minute walk distance

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Disclosure

Ethics approval and informed consent

Only patients who had volunteered and provided written informed consent in accordance with the Declaration of Helsinki were included in this study. The iTrain study was approved by the Regional Committee for Medical and Health Research Ethics in Norway (2014/676/REK nord), the North Denmark Region Committee on Health Research Ethics (N-20140038), and the Alfred Hospital Human Research Ethics Committee (289/14). The HomeBase study was approved by the Alfred Hospital Human Research Ethics Committee (261/11), Austin Health Human Ethics Committee (H2011/04364) and La Trobe University Faculty of Health Sciences Human Ethics Committee (11-134). Approval to combine data from the HomeBase study with the iTrain study has been received. Trial registration: Clinical Trials registry NO.: NCT02258646 and NCT01423227.

Consent for publication

Not applicable.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

P.Z., A.H., B.D, and A.E.H. are responsible for the iTrain study protocol. A.E.H. is responsible for the HomeBase study protocol. H.H., P.Z. and A.E.H. contributed to the conception and design of the current study. H.H., P.Z., B.D., A.T.B., N.S.C., and A.E.H. contributed to the acquisition of data and analysis of data. H.H., P.Z., A.H., A.T.B., N.S.C., A.E.H. contributed to the interpretation of data. H.H., P.Z., A.H., and A.E.H. contributed to drafting the manuscript, and all other authors contributed to revision of the manuscript. All authors read and approved the final manuscript.

References

1. Kohl 3rd HW, Craig CL, Lambert EV, et al. The pandemic of physical inactivity: global action for public health. *Lancet.* 2012;380(9838):294-305.
2. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med.* 2005;171(9):972-977.
3. Park SK, Richardson CR, Holleman RG, Larson JL. Physical activity in people with COPD, using the National Health and Nutrition Evaluation Survey dataset (2003–2006). *Heart Lung* 2013;42(4):235-240.

4. Troosters T, van der Molen T, Polkey M, et al. Improving physical activity in COPD: towards a new paradigm. *Respir Res.* 2013;14:115.
5. Watz H, Pitta F, Rochester CL, et al. An official European Respiratory Society statement on physical activity in COPD. *Eur Respir J.* 2014;44(6):1521-1537.
6. Waschki B, Kirsten A, Holz O, et al. Physical activity is the strongest predictor of all-cause mortality in patients with COPD: a prospective cohort study. *Chest* 2011;140(2):331-342.
7. Furlanetto KC, Donária L, Schneider LP, et al. Sedentary behavior is an independent predictor of mortality in subjects with COPD. *Respir Care.* 2017;62(5):579-587.
8. Van Remoortel H, Hornikx M, Demeyer H, et al. Daily physical activity in subjects with newly diagnosed COPD. *Thorax.* 2013(68):962-963.
9. Waschki B, Kirsten AM, Holz O, et al. Disease progression and changes in physical activity in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med.* 2015;192(3):295-306.
10. Goldcopd.org [homepage on the Internet]. The Global Initiative for Chronic Obstructive Lung Disease (GOLD). Global strategy for the diagnosis, management and prevention of chronic obstructive pulmonary disease 2018 Report. 2018 Available from: https://goldcopd.org/wp-content/uploads/2017/11/GOLD-2018-v6.0-FINAL-revised-20-Nov_WMS.pdf Accessed August 14, 2018.
11. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet.* 2012;380(9838):247-257.
12. Pitta F, Breyer M-K, Hernandes NA, et al. Comparison of daily physical activity between COPD patients from Central Europe and South America. *Respir Med.* 2009;103(3):421-426.
13. Demeyer H, Burtin C, Van Remoortel H, et al. Standardizing the analysis of physical activity in patients with COPD following a pulmonary rehabilitation program. *Chest.* 2014;146(2):318.
14. Sewell L, Singh SJ, Williams JEA, Morgan MD. Seasonal variations affect physical activity and pulmonary rehabilitation outcomes. *J Cardiopulm Rehabil Prev.* 2010;30(5):329-333.
15. Sumukadas D, Witham M, Struthers A, McMurdo M. Day length and weather conditions profoundly affect physical activity levels in older functionally impaired people. *J Epidemiol Community Health.* 2009;63(4):305-309.
16. Balish SM, Dechman G, Hernandez P, et al. The relationship between weather and objectively measured physical activity among individuals with COPD. *J Cardiopulm Rehabil Prev.* 2017;37(6):445-449.
17. Koskela HO. Cold air-provoked respiratory symptoms: the mechanisms and management. *Int J Circumpolar Health.* 2007;66(2):91-100.
18. Hansel NN, McCormack MC, Kim V. The effects of air pollution and temperature on COPD. *COPD.* 2016;13(3):372-379.
19. Zanaboni P, Dinesen B, Hjalmarsen A, et al. Long-term integrated telerehabilitation of COPD Patients: a multicentre randomised controlled trial (iTrain). *BMC Pulm Med.* 2016;16(1):126.
20. Holland AE, Mahal A, Hill CJ, et al. Home-based rehabilitation for COPD using minimal resources: a randomised, controlled equivalence trial. *Thorax.* 2017;72(1):57-65.
21. Weatherspark.com [homepage on the Internet]. San Francisco, United States: Cedar Lake Ventures: Average Weather For Tromsø, Norway. Available from: https://weatherspark.com/y/84211/Average-Weather-in-Tromsø-Norway-Year-Round. Accessed October 1, 2016
22. Weatherspark.com [homepage on the Internet]. San Francisco, United States: Cedar Lake Ventures: Average Weather For Esbjerg, Denmark. Available from: https://weatherspark.com/averages/28824/Esbjerg-Syddanmark-Denmark. Accessed: October 1, 2016.
23. Weatherspark.com [homepage on the Internet]. San Francisco, United States: Cedar Lake Ventures: Average Weather For Melbourne, Australia. Available from: https://weatherspark.com/averages/34069/Melbourne-Victoria-Australia. Accessed: October 1, 2016.

24. Stenton C. The MRC breathlessness scale. *Occup Med.* 2008;58(3):226-227.
25. Holland AE, Spruit MA, Troosters T, et al. An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. *Eur Respir J.* 2014;44(6):1428-1446.
26. Byrom B, Rowe DA. Measuring free-living physical activity in COPD patients: deriving methodology standards for clinical trials through a review of research studies. *Contemp Clin Trials.* 2016;47:172-184.
27. Norton K, Norton L, Sadgrove D. Position statement on physical activity and exercise intensity terminology. *J Sci Med Sport.* 2010;13(5):496-502.
28. Demeyer H, Burtin C, Hornikx M, et al. The minimal important difference in physical activity in patients with COPD. *PLoS One*. 2016;11(4):e0154587.
29. Prosperity.com [homepage on the Internet]. London, United Kingdom: Legatum Institute Foundation: Legatum Prosperity Index TM. 2016. Available form: http://www.prosperity.com/rankings. Accessed March 23, 2017.
30. Troosters T, Sciurba F, Battaglia S, et al. Physical inactivity in patients with COPD, a controlled multi-center pilot-study. *Respir Med*. 2010;104(7):1005-1011.
31. Globalphysicalactivityobservatory.com [homepage on the Internet]. Global observatory for physical activity: Country cards. 2017. Available from: http://www.globalphysicalactivityobservatory.com/country-cards/. Accessed June 22, 2017.
32. Dyrstad SM, Hansen BH, Holme IM, Anderssen SA. Comparison of self-reported versus accelerometer-measured physical activity. *Med Sci Sports Exerc.* 2014;46(1):99-106.
33. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc.* 2007;39.
34. Thorpe O, Kumar S, Johnston K. Barriers to and enablers of physical activity in patients with COPD following a hospital admission: a qualitative study. *Int J Chron Obstruct Pulmon Dis.* 2014;9(1):115-128.
35. Burtin C, Langer D, Van Remoortel H, et al. Physical activity counselling during pulmonary rehabilitation in patients with COPD: a randomised controlled trial. *PLoS One.* 2015;10(12):e0144989.
36. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJF, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet.* 2012;380(9838):258-271.
37. Wilmot EG, Edwardson CL, Achana FA, et al. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. *Diabetologia.* 2012;55(11):2895-2905.
38. Maclay JD, McAllister DA, MacNee W. Cardiovascular risk in chronic obstructive pulmonary disease. *Respirology.* 2007;12(5):634-641.
39. Lahham A, McDonald CF, Holland AE. Exercise training alone or with the addition of activity counseling improves physical activity levels in COPD: a systematic review and meta-analysis of randomized controlled trials. *Int J Chron Obstruct Pulmon Dis.* 2016;11:3121-3136.
40. Gibbs BB, Brach JS, Byard T, et al. Reducing sedentary behavior versus increasing moderate-to-vigorous intensity physical activity in older adults. *J Aging Health.* 2017;29(2):247-267.
41. Togo F, Watanabe E, Park H, Shephard RJ, Aoyagi Y. Meteorology and the physical activity of the elderly: the Nakanojo Study. *Int J Biometeorol.* 2005;50(2):83-89.
42. Alahmari AD, Mackay AJ, Patel AR, et al. Influence of weather and atmospheric pollution on physical activity in patients with COPD. *Respir Res.* 2015;16(1):71.
43. Wan ES, Kantorowski A, Homsy D, et al. Promoting physical activity in COPD: Insights from a randomized trial of a web-based intervention and pedometer use. *Respir Med.* 2017;130:102-110.