ORIGINAL RESEARCH

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

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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: A cross-sectional study where 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 from Norway (N=38), Denmark (N=36) and Australia (N=94). After controlling for disease severity, time spent in awake sedentary time was greater in Danish participants compared to the other countries (median 784 minutes/day [660–952] vs 775 minutes/day [626–877] for Norwegians vs 703 minutes/day [613–802] for Australians, P=0.013), whilst time spent in moderate to vigorous physical activity was lower (median 21 minutes/day [4–73] vs 30 minutes/day [7–93] for Norwegians vs 48 minutes/day [19–98] for Australians, P=0.024). Participants walked 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: After controlling for disease severity, Danish participants spent more time in an awake sedentary state and less time in moderate to vigorous physical activity than their counterparts in Norway and Australia. People with COPD increased their physical activity in summer compared to other seasons. Weather conditions and seasonal variations may influence outcomes in clinical trials and health registries measuring physical activity over time, irrespective of the interventions delivered, and should be taken into account when interpreting results.

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, exacerbations and comorbidities may also lead to decreased physical activity.[5] 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] Socioeconomic 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 socioeconomic and ethnic characteristics, the percentage of Austrians performing less than 30 minutess 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.[13–17] Winter months with cold temperatures have an impact on lung function and the risk of exacerbations.[18,19] However, extremes of hot weather have also been linked to increased morbidity among those with COPD.[19] 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] In one study comparing physical activity levels between summer and winter within the same group of people with COPD in Belgium and Brazil, physical activity levels varied considerably according to the season, even when climate differences between winter and summer were less pronounced.[17]

There are a growing number of studies showing that physical activity levels among people with COPD can vary between countries and that seasonal variations can influence physical activity behavior in patients from different world regions. However, the body of evidence is still limited, and variations in physical activity levels among people with COPD across countries and seasons still deserves further investigation.

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 the seasons (winter, spring, summer, autumn). We hypothesized that Nordic

patients might have lower physical activity levels than Australian patients due to lower average temperatures. We also hypothesized a difference in physical activity levels between winter and summer. Exploring physical activity patterns and seasonal variations in physical activity across countries can support interpretation of data from clinical studies where physical activity is an outcome.

Material and methods
Study subjects and design
Study subjects were a cross-sectional convenience sample of 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 multicenter randomized controlled trial on telerehabilitation for people with COPD in Norway, Denmark and Australia.[20] The HomeBase study was a randomized controlled trial investigating home-based pulmonary rehabilitation for people with COPD in Australia.[21] 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 and 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.[22]

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.[23]

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.[24]

Data collection and analysis

Data on participant characteristics included country, gender, age, body mass index (BMI), number of comorbidities, smoking history, lung function measured by spirometry,[25] 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),[26] and functional walking capacity measured by the 6 minutes walk distance (6MWD).[27]

Physical activity levels were objectively assessed at baseline, prior to any implementation of interventions, with an activity monitor (SenseWear Armband, BodyMedia, Inc., Pittsburgh, PA. USA) which has been also validated for people with COPD.[28] The SenseWear Armband is an advanced, lightweight microprocessor-based device that is worn over the left triceps.[28] Participants were asked to wear the activity monitor continuously for 7 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.[13,29] 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 minute 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.[29] 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.[30]

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 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-normal 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 (IBM Corporation, Armonk, NY, USA).

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.

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 ($F_{(2,165)}$ =3.760, P=0.025, $F_{(2,165)}$=4.347, P=0.014 and $F_{(2,165)}$ =4.693, P=0.010, respectively). After controlling for FEV_1, differences in time spent in MVPA and awake sedentary time across countries persisted ($F_{(2,168)}$ =3.800, P=0.024 and $F_{(2,168)}$=4.431, P=0.013, respectively), while the difference for daily number of steps was no longer statistically significant.

Effect of seasonal variations on physical activity levels

The median (IQR) number of steps for all patients was highest in summer (3,502; 1,253–5,407 steps/day) with lower levels in spring (2,698; 1,613–5,207 steps/day), winter (2,373; 1,145–4,206 steps/day) and autumn (1,603; 738–4,040 steps/day), $F_{(3,164)}$=2.109, P=0.101. The difference between summer and other seasons exceeded the minimal clinically important difference of 600 steps/day.[31] Total MVPA time was also highest during summer. Nevertheless, there were no statistically significant differences among seasons for any of the physical activity variables (Table 3).

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 country was confirmed (P=0.018). The interaction effect between seasons and country 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 country was confirmed (P=0.044). The interaction effect between seasons and country on MVPA time was not statistically significant (P=0.801). There was no significant main effect for season (P=0.633), but there was a significant main effect for country (P=0.042).

Discussion

This study aimed to investigate 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 at establishing whether variations in physical activity levels were attributable to seasons. Although it did not reach statistical significance, participants walked 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, have been observed before. A study on participation in physical activity among Austrian and Brazilian people with COPD, suggested that Brazilian participants, due to lower socioeconomic 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 socioeconomic standards,[32] 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

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[a]
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	AU vs NO=0.009 DK vs AU=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	DK vs NO=0.003 AU vs NO=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	AU vs NO=0.008 DK vs AU=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	DK vs NO=0.001 DK vs AU=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	DK vs NO=0.001 DK vs AU=0.001
FVC, % predicted	74.7 (67.0–90.0)	65.5 (48.5–78.0)	74.0 (62.0–90.0)	0.011	DK vs NO=0.013 DK vs AU=0.004
Disease severity				<0.001	
GOLD II	20 (53%)	3 (8%)	40 (43%)		
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	DK vs NO=0.001 DK vs AU=0.001
Lowest SpO$_2$ during 6MWD, %	90 (86–93)	90 (86–92)	90 (86–93)	0.978	
Max HR during 6MWD, beats 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	DK vs NO=0.001 DK vs AU=0.002
RPE end of 6MWD, Borg CR-10 scale[b]	4 (2–6)	3 (2–4)	3 (2–5)	0.432	
Gait aid, yes	2 (5%)	6 (17%)	8 (9%)	0.218	

Notes: [a]Only significant comparisons are listed. [b]For the Australian participants, this variable was only calculated for the 33 participants in the iTrain study. Data is presented as median (IQR) for continuous variables, and counts (percentages) for categorical variables. A pack year is defined as twenty cigarettes smoked every day for one year.
Abbreviations: 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; SpO$_2$, peripheral capillary oxygen saturation; HR, heart rate; SOB, rating of perceived shortness of breath; RPE, rating of perceived exertion for leg fatigue; DK, Denmark; NO, Norway; AU, Australia.

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, minutes/day	1,361 (1,340–1,414)	1,429 (1,408–1,437)	1,418 (1,401–1,429)	0.001	DK vs NO&AU NO vs AU	
Energy expenditure, kJ/day	9790 (8,237–11,754)	8439 (7,772–9,641)	8320 (7,569–10,843)	0.266		0.288
Steps, number/day	1672 (1,020–3,839)	1534 (778–3,194)	2916 (1,316–4,986)	0.025	DK vs AU	0.133
Awake sedentary time, minutes/day	775 (626–877)	784 (660–952)	703 (613–802)	0.010	DK vs AU	0.013
Total LIPA, minutes/day[a]	158 (81–219)	178 (124–234)	208 (132–249)	0.388		0.422
Total MVPA, minutes/day	30 (7–93)	21 (4–73)	48 (19–98)	0.014	DK vs AU	0.024
Time in MVPA bouts, minutes/day	8 (0–30)	4 (0–26)	7 (0–24)	n.a.		n.a.

Notes: DK vs NO&AU, NO vs AU and DK vs AU = P-value ≤0.050, only significant comparisons are listed. [a]LIPA for the Australian sample was available for the 33 participants in the iTrain study only. Data are median (IQR).
Abbreviations: LIPA, light-intensity physical activity; MVPA, moderate-to-vigorous physical activity; n.a., nonapplicable; DK, Denmark; NO, Norway; AU, Australia.

in patients with COPD.[5,33] 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 multicenter and multinational trials.

For the healthy population, the country of residence 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.[34] 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

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 (7,796–10,297)	8571 (7,748–11,783)	8491 (7,642–11,164)	8442 (7,261–10,314)	0.181
Steps, number/day	2373 (1,145–4,206)	2698 (1,613–5,207)	3502 (1,253–5,407)	1603 (738–4,04)	0.101
Awake sedentary time, minutes/day	721 (608–868)	755 (635–901)	700 (617–801)	735 (620–824)	0.796
Sleep time, minutes/day	410 (316–463)	362 (316–451)	365 (317–481)	401 (314–463)	0.982
Total LIPA, minutes/day[a]	160 (102–237)	197 (150–255)	159 (99–251)	177 (106–230)	0.487
Total MVPA, minutes/day	39 (15–88)	38 (20–100)	62 (11–108)	27 (8–90)	0.326
Time in MVPA bouts, minutes/day	9 (0–23)	7 (0–34)	7 (2–25)	5 (0–25)	n.a.

Notes: [a]LIPA for the Australian sample was available for the 33 participants in the iTrain study only. Data are presented as median (IQR).
Abbreviations: LIPA, light-intensity physical activity; MVPA, moderate-to-vigorous physical activity; n.a., nonapplicable; NO, Norway; DK, Denmark; AU, Australia.

and accelerometer-measured physical activity and sedentary time have been reported.[35]

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 m 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.[36] Such correlation between physical capacity and intensity of physical activity has previously 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.[37,38]

Reducing sedentary time can decrease cardiovascular risk in other patient groups.[39] As many patients with COPD have cardiovascular comorbidities,[40] strategies to reduce sedentary time may be clinically relevant in COPD.[41] 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.[42] 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.[41] 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 a lower number of steps during rainy and colder days, in winter and during extreme summer heat.[14,16,17,43,44] 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 an Arctic climate with cold summers and cold winters to tropically influenced climate with warm summers and mild winters. Participants with COPD walked more during summer than during spring, winter and autumn, regardless of location. Results did not reach statistical significance perhaps due to the modest sample size in each group. However, the overall difference between summer (3,502 steps/day) and winter (2,373 steps/day) exceeded the minimal clinical important difference (between 600 and 1,100 steps/day) in daily step count after pulmonary rehabilitation.[31] An improvement of more than 600 steps/day after pulmonary rehabilitation is also reported to reduce the risk of hospitalization in patients with COPD.[31] We therefore consider the difference of 1,129 daily steps between summer and winter to be of clinical relevance. In the current study, time spent in MVPA during winter was also found to be 37% lower than in summer. Interestingly, another study found a significant reduction of the time spent actively during winter when compared to summer among both Brazilian and Belgian people with COPD. Such a difference was even more evident in patients from Brazil (20% vs 12% in Belgium), although Brazil has lower variations in temperature between summer and winter than Belgium.[17] In the current study, the data collected during winter had a higher percentage of participants from the Nordic countries than those collected during summer. This may, in part, explain the difference with the findings from Furlanetto et al.[17]

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-month physical activity intervention trial on people with COPD.[45] An increase in daily steps was found in subgroup analysis of both a group receiving a pedometer and web-based support and of 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.[45] The influence of seasonal variations on physical activity habits may be relevant for selected patient groups, such as COPD, as well as for the healthy population. Results from multinational 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 cross-sectional convenient sample 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. The study also has some limitations. 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. Sample power was not computed beforehand, and 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 both for 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 nonparametric 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 cross-sectional study, time spent in awake sedentary time was greater in Danish participants compared to the Norwegian and Australian participants after controlling for disease severity, whilst time spent in MVPA was lower. The number of steps for all patients was highest in summer with lower levels in spring, winter and autumn, regardless of geography. In particular, the overall difference between summer and winter exceeded the minimal clinical important difference in daily step count after pulmonary rehabilitation. Weather conditions and seasonal variations may influence outcomes in clinical trials and health registries

measuring physical activity over time, irrespective of the interventions delivered, and should be taken into account when interpreting results.

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.

Data sharing statement

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

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Author contributions

PZ, AH, BD, and AEH are responsible for the iTrain study protocol. AEH is responsible for the HomeBase study protocol. HH, PZ, and AEH contributed to the conception and design of the current study. HH, PZ, BD, ATB, NSC, and AEH contributed to the acquisition of data. All authors contributed toward data analysis, drafting and critically revising the paper, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Disclosure

The authors declare that they have no competing interests. Dr Narelle Cox reports honorarium paid by Boehringer Ingelheim for workshop delivery regarding pulmonary rehabilitation and exercise in COPD. The authors report no other conflicts of interest in this work.

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