Use of a consumer market activity monitoring and feedback device improves exercise capacity and activity levels in COPD

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***Abstract*— COPD is associated with a gradual decline in physical activity, which itself contributes to a worsening of the underlying condition. Strategies that improve physical activity levels are critical to halt this cycle. Wearable sensor based activity monitoring and persuasive feedback might offer a potential solution. However it is not clear just how much intervention might be needed in this regard – i.e. whether programmes need to be tailored specifically for the target clinical population or whether more simple activity monitoring and feedback solutions, such as that offered in consumer market devices, might be sufficient. This research was carried out to investigate the impact of 4 weeks of using an off the shelf consumer market activity monitoring and feedback application on measures of physical activity, exercise capacity, and health related quality of life in a population of 10 Stage I and II COPD patients. Results demonstrate a significant and positive effect on exercise capacity (measured using a 6-minute walk test) and activity levels (measured in terms of average number of steps per hour) yet no impact on health related quality of life (St Georges Respiratory Disease Questionnaire).**

I. Introduction

The critical role of physical activity in the promotion of health and management of disease is well recognized. Its relevance to Chronic Obstructive Pulmonary Disease (COPD) has increasingly become of interest due to its relation with patient outcomes, prognosis of disease, and co-morbidities (1).

The simple fact is that COPD patients are not a physically active population. Waschki et al. have reported that healthy subjects on average took over 10,000 steps per day, whereas COPD patients in GOLD stage II performed only 7,139 steps on average per day (2). A more recent study has demonstrated that 33% of COPD patients in GOLD stage I and II take on average less than 5,000 steps per day (3), generally considered to be the threshold for sedentarism (4). Similarly, time spent in mild and moderate physical activities is reduced in patients with COPD (5) compared to healthy controls. Moreover, the outcome may lead to worsened symptoms, anxiety and depression. To combat and manage these findings, the World Health Organization (WHO) suggest that all patients with COPD benefit from exercise training programs, with improvements to exercise tolerance and symptoms of dyspnea and fatigue. However, in routine practice, there is still a deficit in promoting the importance of physical activity. Jochmann et al have reported that only 23% of COPD patients report exercising regularly (6).

So, there is a need to explore alternative strategies for promotion of increased levels of physical activity in the COPD population. The use of accelerometer based physical activity monitoring and feedback has achieved widespread attention in recent years, with the advent of inexpensive applications such as Nike Fuel Band and the Fitbit range of products. Typically, these products have been aimed at the consumer market, with a 'wellness' or personal fitness application in mind. The proposition is simple, that quantification and provision of feedback relating to physical activity generates an awareness and motivation that influences a positive behavior change. Since COPD patients have a hard time remaining and feeling motivated to be physically active, similar interventions have been proposed in the field. In a recent trial, an accelerometer was used to monitor physical activity of a cohort of COPD patients. Each participant was given a smart phone that showed the feedback based on their activity and tailored to personal goals. The data was connected to a server that stored the data and sent feedback to the patients, as well as providing a summary report to clinicians. The study revealed positive results in terms of increases in time spent in physical activity, improvements in quality of life, and motivation levels (7).

However, this study was based on a targeted intervention that was designed specifically for COPD patients. It may be that the consumer devices discussed above could also have application in populations with chronic diseases, such as COPD, as they have the potential to engage patients and influence positive behavior change with regard to physical activity. If they were effective in this regard they would constitute a very attractive proposition due to their ease of use and low cost. To date, we have not found any reports of applications of such consumer devices in the COPD population, perhaps a reflection of a belief amongst clinicians that such a simple approach would not be sufficient to unlock the cycle of physical inactivity that is associated with COPD. Therefore, in this study we sought to undertake a pilot implementation and evaluation of a simple consumer health device, the Fitbit One, in a population of COPD patients. In particular we investigated the impact of providing these devices for a period of time, without any clinical support, on measures of physical exercise capacity, physical activity, health related quality of life, and intrinsic motivation.

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II. METHODS

A. Study Participants

Ten volunteer participants (5f, 5m; BMI 28.4±4.0Kg.m^2; age 61.4 ± 5.7years), volunteered to take part in the study. All participants were attending a specialised COPD clinic in a local acute tertiary care hospital and met the inclusion criteria for the study (clinical diagnosis of COPD with a GOLD Stage I or II classification; aged between 50 and 80; able to follow instructions; and cleared for exercise participation by their medical consultant). Participants were excluded if they had any contraindications to exercise participation or were experiencing an exacerbation of their COPD that was likely to impede their ability to engage in physical activity. Each participant received a clear explanation of what the study involved and written consent was obtained.

B. Study Design

This was a prospective case control study in which we followed each study participant for a period of 6 weeks with 3 measurement points in each case. Measures of exercise capacity and health related quality of life were taken at baseline, following a 2 week period in which study participants wore the activity monitoring device without any feedback (monitoring phase), and following 4 weeks of use of the activity monitoring device with availability of online and on-device feedback (monitoring & feedback phase). All baseline and follow-up testing was performed in the hospital clinic.

C. Exercise Capacity Evaluation

Cardiovascular exercise capacity was assessed using a six-minute walk test (8) along a 20m stretch of indoor track. Participants were instructed to walk as far as possible in six minutes, back and forth along the track, turning briskly around the cones at each end. Participants were allowed to slow down, stop and rest as necessary but were to continue walking as soon as they were able. Participants were instructed not to talk during the test unless a question was asked of them or if they experienced chest pain or dizziness. Standardized verbal encouragements were given by the tester after every minute. Heart rate and oxygen saturation levels were recorded using a portable pulse oximeter (2500 Nonin Medical Inc., Plymouth, MN, USA). Participants rated their perceived exertion on the Borg RPE Scale. Participants were seated for two minutes after completing the walking test.

D. Health Related Quality of Life Evaluation

Health related quality of life was measured using the St Georges Respiratory Disease Questionnaire (9). This is a widely used questionnaire designed specifically for use in patients with asthma and COPD. IT consists of 16 questions divided into 2 sections. Section 1 (Qs1-8) deals with frequency of respiratory symptoms, while section 2 (Qs9-16) are concerned with the patient's current state. IT is self administered, with support from a healthcare professional as appropriate, and scoring is done using an Excel spreadsheet provided by the questionnaire developers. There are 3 separate component scores (Symptoms, Activity, and Impact) and a Total score. Lower scores on each component, or total score, indicate better health.

E. Motivation Evaluation

Motivation for the task (in this case, engagement on physical activity) was evaluated using the Intrinsic Motivation Inventory assessment tool (10).

F. Fitbit Intervention

All study participants were provided with a standardized technology support package throughout the study. This consisted of a Fitbit One (Fitbit, California, USA) accelerometer based activity monitoring and feedback device, a laptop computer with an auto execute web browser application set to log in to the participant's own Fitbit account, and a mobile broadband modem. This setup was implemented to avoid any potential issues around study participants having technical challenges associated with using a computer or connecting to the internet. All study participants received a home visit for installation and testing or equipment, as well as a full briefing on the mode of use of all devices.

During the first 2 weeks the laptop was set up to receive data each day from the fitbit without provision of any feedback to the study participant. At the same time, the study coordinator was able to log into the participant's account to ensure that data was being collected. As well as not being able to access their own account, and associated feedback, participants also could not see feedback on the fitbit device itself. This was achieved by means of occluding the device display with what participants were told was a device identification label that could not be removed. In this way, participants used the fitbit to simply record their activities during the first 2 weeks without provision of any feedback.

At the end of the 2nd week the study coordinator visited the participant's home again and set up the web browser to enable them to log in to their individual account. At the same time they were provided with instruction in the functionality of the Fitbit service, in terms of the various feedback displays and supports available. They were encouraged to visit their Fitbit page as often as they felt necessary, and were provided with no further instruction regarding physical activity participation. The label that had been occluding the on-device display was also removed at this home visit, thus enabling participants to receive instantaneous feedback regarding steps taken and stairs climbed at any stage.

Participants were encouraged to wear the fitbit during their waking hours. Most chose to wear it on their belt or pocket. Each participant received regular calls and texts to remind them to wear the device. It is important to note that we did not request that participants pay attention to the sleep monitoring and feedback functionality of the device at any stage during the study as our interest was primarily on physical activity

Figure 1. The Fitbit One device.

G. Statistical Analysis

We obtained 6-minute walk distances (M) and SRGQ scores from each participant at baseline, following the monitoring phase (Week 1-2), and following the monitoring and feedback phase (Week 3-6). Repeated measures ANOVA F-tests were carried out to test for differences across the 3 measurement points for each variable of interest. Subsequent to this, where ANOVA proved significant, post hoc paired 2-sided t-tests were performed to test for differences between baseline and week 2, week 2 and week 6 and baseline and week 6 respectively.

Analysis of physical activity changes during the study period was by means of analysis of the average number of steps taken each hour during the period of usage in both monitoring and monitoring and feedback phases. Steps was averaged per hour of use in order to account for differences in the total hours of usage during each phase, as participants did not always wear the device for a consistent period each day. So, the average number of steps taken per hour during weeks 1 and 2 was compared to average number of steps taken per hour during weeks 3 through 6, using paired 2-sided t-tests.

Intrinsic motivation inventory scores were analysed at follow-up using descriptive statistics. The level of significance was set at $P<0.05$.

III. Results

All study participants completed the study without any problems or exacerbations of their disease. Subjective reports suggested that the technology was well received with no reports of technical problems during usage. The main issue that participants had with the technology package was concerned with remembering to put the device on each morning.

Results for exercise capacity, health related quality of life, physical activity and motivation are detailed in the tables below. We observed significant improvements in 6-minute walk distance, average number of steps taken per hour. However there were no changes in health related quality of life – none of the component scores or the total score for the SRGQ were different at any of the measurement intervals.

Table 1. Group mean (SD) values for Exercise Capacity and Health Related Quality of Life at baseline, following the monitoring phase, and following the monitoring and feedback phase.

	Baseline (Week 0)	Post Monitoring Phase (Week 2)	Post Monitoring & Feedback Phase (Week 6)	Within Group Effects Level of Significance
6-minute Walk Distance (M)	397.5(121.6)	420.0(132.7)	515.1(141.1)	P<0.05
SQGQ Symptoms Score	54.7(23.6)	58.1(24.4)	57.8(24.0)	P>0.05
SQGQ Activity Score	49.9(19.4)	49.8(21.1)	52.9(18.8)	P>0.05
SQGQ Impact Score	31.9(15.0)	31.1(17.8)	31.4(14.5)	P>0.05
SQGQ Total Score	41.0(15.5)	41.4(16.6)	42.3(12.4)	P>0.05

All values are group mean (SD). Level of significance calculated using repeated-measures ANOVA *F*-test (sphericity assumed).

Table 2. Post hoc comparisons between conditions (where significance observed at ANOVA).

	Baseline Vs Post Monitoring Phase	Post Monitoring Phase Vs Post Monitoring & Feedback Phase	Baseline Vs Post Monitoring & Feedback Phase
6-minute Walk Distance (M)	0.49	0.00001	0.002

Values are P values, calculated using 2-sided paired t-tests

Table 3. Group mean (SD) physical activity in monitoring phase and monitoring and feedback phase.

	Monitoring Phase	Monitoring & Feedback Phase	Level of Significance
Average Steps Taken Per Hour	310.0(107.9)	370.3(128.5)	P=0.034

All values are group mean (SD). Level of significance calculated using 2-sided paired t-tests

IV. Discussion

Activity limitation is one of the primary symptoms of COPD and progressively worsens over time. COPD patients often

have a low level of physical activity that itself leads to further deterioration in their condition and a downward spiral that is difficult to halt. The results from this study are very encouraging as they show that a simple, off the shelf consumer device such as fitbit can potentially be used to induce a positive change in behavior. However, we did not observe any changes in health related quality of life so the study suggests that further analysis of the length of time required to induce a change in perceived health is required.

The changes observed in 6-minute walk distance are very encouraging. Total distance covered during the 6-minute test improved by approximately 25%, or 100m, on average during the intervention and feedback phase. This is clinically significant finding, and well above the threshold for minimal detectable change.

This improvement in 6-minute walk distance was associated with a similarly impressive improvement in the average number of steps taken, normalized to a per hour basis, during the monitoring and feedback phase. These results are interesting as they tell us a few things. Firstly, the average number of steps taken on a daily basis by our participants was very low, with the vast majority taking less than the 5000 steps considered the threshold for sedentarism. Secondly, the relative stability of the number of steps taken during the monitoring phase suggests that monitoring alone does not significantly impact on likelihood to participate in physical activity. On the other hand, an increase of approximately 70 steps per hour on average during the monitoring and feedback phase is very impressive as it points to an improvement of approx. 840 steps per day if extrapolated out over a 12 hour period. This represents a very significant improvement considering the low baseline.

Analysis of the intrinsic motivation inventory scores suggest that the technology support was very well accepted by the study participants and it appeared to point towards a high level of motivation for the task. Anecdotally, we observed a very positive attitude towards the technology support, and associated feedback, in the study cohort. However, one must caution against too much optimism in this regard as we have not followed up this cohort of patients over an extended period of time and there is no guarantee that use of devices such as fitbit would have longstanding attraction and impact in this population over time. Indeed, there is emerging evidence from the healthy population that longstanding traction has proved challenging with devices such as fitbit, pointing to a difficulty in maintaining interest and motivation to engage with them over extended periods.

We also failed to observe any impact whatsoever on measures of health related quality of life during the study period. This is not surprising considering the relatively short intervention period and the time lag between physical improvements and perceived health related quality of life changes. It may be that positive changes would manifest over a longer period of time. Against that we must be open to the idea that usage might not remain sufficiently interesting over extended periods, as discussed above.

Finally, it is worth noting that the measurement validity and accuracy of devices such as fitbit is not clear. This is not helped by failure of the manufacturers to release details of the technical performance of their devices and associated data processing algorithms. However, it is also unclear as to what level of accuracy is actually required for the intended application in the marketplace and it is entirely feasible that a low level of measurement granularity is sufficient for the intended purpose.

V. Conclusion

This study provides encouraging results regarding the potential impact of consumer activity monitoring and feedback devices in COPD patients. However, the long term effects of such devices, and the relative impact of disease specific device/application combinations versus generic consumer devices required a lot of further attention.

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