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The Impact of a 12-Month Activity Tracker Intervention on Activity Behavior Across Body Mass Index Subgroups Among Recent Retirees: Post Hoc Analysis of a Randomized Controlled Trial

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ABSTRACT

Background: This study examined the effectiveness of a 12-month activity tracker based intervention on activity behavior among recent retirees (REACT) in subgroups based on body mass index (BMI).

Methods: REACT trial randomized 231 participants (mean age 65.2) into intervention and control groups. Main outcomes were accelerometer-measured moderate-to-vigorous (MVPA) and light physical activity (LPA) and sedentary time (SED) measured at baseline and 3-, 6- and 12-month follow-ups. As a post-hoc analysis, the intervention effect was examined among participants with normal weight (n=77), overweight (n=89), and obesity (n=61).

Results: An intervention effect was observed among participants with obesity in LPA (time*group p=0.045) mirrored by a similar, albeit non-significant, effect in SED (p=0.067), but not in MVPA (p=0.92). A transient increase of 41 min/day (95% CI 14 to 68) in LPA was observed at six months among the intervention group, with a concomitant decrease of 42 min/day (-72 to -12) in SED. However, these changes were not maintained at 12 months. No between-group differences in changes over time were observed among participants with normal or overweight.

Conclusions: Activity trackers may be particularly suitable for promoting changes in LPA and SED among older adults with obesity. However, their long-term effectiveness might be limited.

Introduction

Physical inactivity and excess body weight are two major risk factors limiting health and functioning with advancing age.[1,2] Physical activity is an important modifiable behavioral factor that protects against accumulation of excess weight and attenuates health risks associated with obesity.[3] However, activity levels decline with age while sedentary time increases.[4]

The use of wearable activity trackers to promote physical activity has increased, also among older adults.[5] Modern activity trackers incorporate various behavior change techniques,[6] are well-received among older adults,[7] and show promise as cost-effective intervention tools.[8] However, previous studies using activity trackers to promote physical activity among older adults have been mainly short-term (<6 months) and highly heterogeneous in terms of intervention contents and physical activity outcome measures used.[5] Studies have shown increases in accelerometer-measured moderate-to-vigorous physical activity (MVPA) and/or steps, while findings for light physical activity (LPA) and sedentary time (SED) have been more ambiguous.[9–13] It appears that inactive participants benefit more on the use of activity trackers,[14] while less conclusive findings have been reported when no prior activity related inclusion criteria have been employed.[9,12] Although likely to be partly attributable to variations in study designs, the mixed findings suggest that among older adults the impact of activity trackers on activity behavior is not likely to be uniform across target populations.

Recent reviews from the weight management literature suggest that participants with excess weight in particular may benefit from interventions utilizing activity trackers.[15,16] However, only a handful of studies reporting accelerometer-measured outcomes have focused specifically on older adults with excess weight.[11,17–19] Interestingly, the results of these studies have been positive, yet mixed. For example, Cadmus-Bertram et al. observed increases in MVPA and steps but not in LPA at 4 months,[11] while Lyons et al. reported increases in steps but no changes in SED at 3 months.[19] Focusing explicitly on older adults with obesity, Nicklas et al. observed increases at 5 months in LPA but not in MVPA or steps,[17] while Rosenberg et al. reported decreases at 3 months in SED but no changes in steps.[18] As activity trackers lend themselves to multiple purposes, some of the variation in the observed results may well be attributable to differences in intervention aims and contents. However, the divergent findings also highlight the possibility that LPA and SED might represent more viable targets for activity tracker-driven behavioral modification among older adults with obesity.[20,21]

The current study is a secondary analysis of the "Enhancing physical ACTivity and healthy aging among recent REtirees (REACT)" randomized controlled trial.[12,13] The REACT trial examined the effectiveness of a 12-month activity tracker based intervention on accelerometer-measured daily activity behavior among community-based sample of recent retirees. The rationale behind the trial was to test a low cost and easily scalable intervention method targeted at an optimal time. Retirement transition has been recently identified as a potentially important time period for promoting physical activity due to increases in time availability.[22] In the 12-month REACT trial the activity tracker and the accompanying web-based software were intended as stand-alone tools for behavioral modification, thus providing an opportunity to examine the relatively independent short- and long-term impacts of activity trackers on accelerometer-measured activity behavior.

The purpose of this secondary analysis was to examine the effectiveness of the REACT trial in increasing MVPA and LPA and decreasing SED in subgroups based on body mass index (BMI).

Methods

Study design

The REACT study design, recruitment, randomization and main results have been reported elsewhere.[12,13] Briefly, REACT was a 12-month randomized controlled trial using wearable activity trackers to promote physical activity among recent retirees. The study enrolled a community-based sample of 231 recently retired public sector workers (mean age 65.2, 83% female, mean BMI 27.2) living in Southwest Finland. Inclusion criteria included having basic knowledge of using a computer and internet at home and not suffering from major functional or health-related limitations to physical activity. Outcome measurements were conducted at baseline and 3-, 6- and 12-month follow-ups. After the baseline measurements, the participants were randomized to intervention (n=117) and control groups (n=114). The participants were allocated in five waves spread throughout the year with 44% having spring (March to May), 25% having autumn (September to November) and 31% having winter (December to February) as the baseline season. For the purposes of the study at hand, the participants with underweight were excluded (n=4). The trial was approved by the Ethics Committee of Hospital District of Southwest Finland and registration was completed (ClinicalTrials.gov: NCT03320746). All participants provided informed consent for their participation in the study. The CONSORT flow diagram and checklist are provided as online supplements (Supporting Information Appendix S1 and S2).

Intervention

The intervention group participants were provided with commercial activity trackers (Polar Loop 2, Polar, Kempele, Finland) after the baseline measurements with instructions to wear them for 12 months while aiming for the 100% attainment of a pre-set daily activity goal inherent in the activity tracker. The daily activity goals had three levels and all the participants started the intervention at level one. The activity tracker included a built-in accelerometer to measure activity with various kinds of activities contributing to the on-going accumulation of daily activity. The accumulation rate of the daily activity goal was also sensitive to the intensity of activity: higher the intensity of activity, the faster the accumulation rate of the daily activity goal. Consequently, there were multiple ways and possible combinations for attaining the daily activity goal. To give a rough estimate of the amount of activity required, the 100% daily activity goal at level one could be accumulated by 57 minutes of jogging, or 2h 11min of walking, or 7h 20min of household activities as per examples provided by the tracker's manufacturer. If a participant frequently exceeded the 100% accumulation of the daily activity goal, a higher level was suggested by the researcher. In addition, the participants were also able to switch between the levels independently. As the activity tracker and the accompanying web-based software were intended as stand-alone tools for behavioral modification, it was left for the participants themselves to decide how to proceed with accumulating daily activity.

The activity tracker displayed the accumulation of daily activity and steps and provided real-time guidance on how to reach the daily activity goal (e.g. "To go: walk for 25 minutes"). After 55 minutes of inactivity, the tracker also vibrated and displayed a prompt *"it's time to move"* on the screen. The intervention group participants were requested to upload data from their trackers to the accompanying web-based software (Polar Flow) once a week. The web-based software allowed for daily/weekly/monthly self-monitoring of activity and sedentary time and provided feedback on the accumulated levels. The research team monitored the tracker data upload on a monthly basis via shared access to the web-based software and sent reminders to participants via email/sms if uploads were constantly missing (e.g. no uploads for two consecutive weeks). The control group participants were requested to abstain from the use of activity trackers during the duration of the study. The intervention content is described in further detail elsewhere.[12]

Measures

Physical activity and sedentary time. The outcome variables were accelerometer-measured (Actigraph wGT3X-BT) average daily minutes of MVPA, LPA and SED. Participants were instructed to wear the accelerometer on their non-dominant wrist for seven days at each measurement point. A day was considered valid if it had at least ten hours of accelerometer wear time and a minimum of four valid days were required for calculating the average daily minutes. Detailed description of the accelerometer measurements is presented elsewhere.[12,13]

Body Mass Index. The participants were divided into three categories based on body weight and height measurements conducted by study nurse at baseline: (1) participants with normal weight ($18.5 \leq$ BMI < 25 kg/m^2; n=77); (2) overweight ($25 \leq$ BMI < 30 kg/m^2; n=89); and (3) obesity (BMI ≥ 30 kg/m^2; n=61).[23]

Background characteristics. Age, sex and occupational history were derived from the Pension Institute's register. Occupational background preceding retirement was categorized into three levels according to the International Standard Classification of Occupations (ISCO): "High" including managers and professionals (ISCO classes 1–2), "intermediate" including associate professional (ISCO classes 3–4), and "low" including manual and service workers (ISCO classes 5–9). Number of doctor diagnosed chronic conditions (none, 1, or >1) was assessed with a questionnaire and the following conditions were considered: angina pectoris, myocardial infarction, stroke, claudication, osteoarthritis, osteoporosis, sciatica, fibromyalgia, rheumatoid arthritis, depression or other mental illness, and diabetes. Limitations in walking two kilometers (yes/no) were assessed with the Short Form SF-36 questionnaire.[12]

Statistical analyses

The current study was a secondary analysis of the REACT randomized controlled trial.[12,13] As the original randomization was not stratified based on BMI, the baseline characteristics between the intervention and control groups within each BMI category were examined with t-tests and chi-square or Fisher's exact tests.

The observed average daily minutes of MVPA, LPA, SED and wear time of the accelerometer by group and time point were summarized using descriptive statistics. The changes in average daily minutes of MVPA, LPA and SED over time were examined with mixed-effects analysis of covariance models for repeated measurements using compound symmetry for longitudinal covariance. Separate models were fitted for each outcome within each BMI category. The models included group as a between-factor, time as a within-factor and a group by time interaction used to examine the intervention effect. Least squares means were obtained and estimate statements were used for within- and between-group comparisons of the changes over time with the baseline as the reference. Due to the exploratory nature of the study, no adjustments for multiple testing were made. The analyses were performed by the intention-to-treat principle, adjusted for wear time of the accelerometer and baseline season, and conducted with SAS Software 9.4 (SAS Institute Inc., Cary, NC).

Due to high dispersion in the observed scores, further analyses were conducted using nonparametric methods to assess the robustness of the findings. To account for the influence of changes in wear time across time points, the amount of MVPA, LPA and SED was expressed as percentages of wear time. To assess the changes over time, difference scores were calculated for each outcome by subtracting the baseline percentage from the time point in question (Time point % – Baseline %). We summarized the difference scores using medians and interquartile ranges and used Wilcoxon Rank Sum tests to examine the between-group differences in changes over time.

For all analyses, p-values below $p<0.05$ (two-tailed) were considered significant.

Results

Participant characteristics at the baseline are presented in Table 1. A significant between-group difference was observed in the baseline seasons among participants with obesity. The baseline seasons were unevenly distributed among the control group participants where spring was the baseline season for 62% whereas only 4% started the study in the autumn and 35% in the winter. No significant differences were observed in the other baseline characteristics between the intervention and control groups within BMI categories.

Table 2 presents the observed average daily minutes of wear time of the accelerometers and number of valid observations at each time point. Descriptive statistics of the observed daily minutes of MVPA, LPA and SED at each time point by group and BMI category are presented in Table 3.

The changes over time in MVPA, LPA and SED among participants with obesity are presented in Figure 1. Among participants with obesity, there was an indication of an intervention effect in LPA (time*group p=0.045), mirrored by a similar, albeit non-significant, effect in SED (p=0.067) whereas no effect was observed in MVPA (p=0.92). The intervention group increased LPA by 41 minutes/day (95% CI 14 to 68) and decreased SED by 42 min/day (95% CI -72 to -12) at six months in relation to baseline, but the levels were not maintained at 12 months. The control group decreased LPA by 12 min/day (95% CI -43 to 19) and increased

SED by 12 min/day (95% CI -22 to 46) at six months in relation to baseline (Supporting Information Table S1).

No between-group differences were observed in changes in MVPA, LPA or SED over time among participants with normal weight (time*group p=0.68, p=0.48, p=0.80, respectively) or overweight (time*group p=0.63, p=0.94, p=0.93) (Supporting Information Table S2–S3 and Figure S1–S2).

The results of the Wilcoxon Rank Sum tests were similar to the ones derived from the adjusted models. Between-group differences were observed at six months among participants with obesity in LPA (p=0.020) and SED (p=0.020). At six months, the median difference from baseline among the intervention group was +4.2% (IQR: -2.4 – 9.7) in LPA and -4.1% (-11.7 – 2.1) in SED. Among the control group, the median difference was -1.4% (-6.9 – 4.4) in LPA and +1.2% (-3.9 – 9.4) in SED (Supporting Information Table S1).

Discussion

Based on a 12-month physical activity intervention using an activity tracker among recent retirees, a transient increase in LPA was observed among participants with obesity, mirrored by a similar decrease in SED. No between-group differences in changes over time were observed in MVPA, or among participants with normal or overweight. This finding extends previous research suggesting that wearable activity trackers may be particularly suitable for promoting changes in daily LPA and SED among older adults with obesity. However, additional intervention methods are likely to be required for their maintenance, or for increasing MVPA.

In the REACT trial, no instructions were given on how to modify physical activity behavior apart from the daily activity goals and inactivity alerts provided by the activity tracker.[12,13] It appears based on the results, that the participants with obesity increased LPA by mainly decreasing SED. This suggests that modifying LPA and SED might represent more attainable and acceptable behavior change targets than MVPA-based goals among older adults with obesity as has been previously suggested.[17,18,20]

While physical activity promotion has traditionally focused on MVPA, recent accelerometer-based research has also linked LPA with desirable cardiometabolic health[24] and functional outcomes.[25] On the other hand, SED, particularly when prolonged, has been found to be negatively associated with cardiometabolic health markers.[26,27] Furthermore, a recent meta-analysis with a mean age of 55.8 years found reallocating 30 minutes of SED into LPA to be associated with reductions in waist circumference and fasting insulin, suggesting that already relatively minor changes to the daily activity profile might be beneficial.[28] Older adults with obesity in particular tend to have high amounts of daily SED[4] and reallocating it to LPA might represent a behaviorally viable option for accumulating daily activity.[17,18,20]

However, the changes observed in the present study were transient suggesting that the independent impact of activity trackers may be limited. The participants would have likely benefitted from a more individual and specific goal setting,[11,17-19,29] the inclusion of both behavioral and behavioral outcome goals,[17,29] or social support provided via frequent telephone[19,29] and/or face-to-face sessions.[17–19] However, it is unclear whether the inclusion of these methods would have contributed to the long-term maintenance of the initial changes as long-term studies using activity trackers as central intervention components among older adults are generally lacking.[5,8] Rather, as activity trackers are inherently extrinsic motivators,[30] their potential might well be limited to short-term effects. The activity trackers may serve best in the initial phases of behavioral modification whereas further methods, such as fostering autonomous motivation, are likely to be required for long-term impact.[31]

The strengths of this study include accelerometer-measured physical activity outcomes, long-term intervention and follow-up as well as the use of an activity tracker that also included features aimed at reducing sedentary time. However, the current study also has some limitations. Firstly, the stratum-specific analyses presented here were based on a post-hoc categorization of the data and were neither preplanned nor adequately powered. As this increases the probability for both type 1 and 2 errors, the results presented here should be interpreted with caution. Secondly, the majority of the study participants were healthy and female, which may limit the generalizability of the findings. Thirdly, wrist-worn accelerometers may not have accurately captured all types of daily activity, such as cycling, which may have some implications for outcome measurement validity.

Conclusion

Wearable activity trackers may be particularly suitable for supporting the trade-off between SED and LPA among older adults with obesity. However, the independent impacts of activity trackers are likely to be short-term. Future studies utilizing wearable activity trackers among older adults with obesity should consider including LPA and SED as behavioral targets of interventions and seek to identify ways to support the long-term maintenance of the initial activity tracker induced changes.

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TL and SS conceived and led the trial and obtained funding. TL, SS, KS, and JP designed the intervention protocol. TL collected the data. KS processed the raw accelerometer data. MT conducted the analyses and drafted the manuscript. TL, PK, SS and JP supervised data analyses and interpretation. All authors provided input into manuscript preparation and approved the final manuscript.

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Trial registration

This study is registered at www.clinicaltrials.gov (No.NCT03320746). Registered 25 October 2017. https://clinicaltrials.gov/ct2/show/NCT03320746

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Table 1. Baseline characteristics by intervention group and body mass index (BMI) category.
SD: standard deviation

	BMI 18.5-25 kg/m^2			**BMI 25-30 kg/m^2**			**BMI ≥ 30 kg/m^2**	
Group	Control (n=39)	Intervention (n=38)		Control (n=45)	Intervention (n=44)		Control (n=26)	Intervention (n=35)
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)
Age, years	65.1 (1.1)	65.2 (1.1)		65.0 (1.3)	65.2 (0.9)		65.4 (0.9)	65.1 (1.1)
BMI, kg/m^2	23.0 (1.6)	22.8 (1.6)		27.2 (1.4)	27.3 (1.5)		33.2 (4.2)	33.3 (3.3)
	%	%		%	%		%	%
Sex								
Male	10	16		20	23		23	14
Female	90	84		80	77		77	86
Occupational background								
High	33	40		33	45		42	34
Intermediate	26	29		29	27		19	34
Low	41	32		38	27		39	31
Number of chronic conditions								
0	49	61		40	50		40	40
1	39	37		49	43		48	49
>1	13	3		11	7		12	11
Limitations in walking 2km								
No	95	100		96	95		92	83
Yes	5	0		4	5		8	17
Baseline season[a]								
Spring	41	42		42	48		62	34
Autumn	28	21		33	25		4	29
Winter	31	37		24	27		35	37

[a] P-value for between-group difference in the baseline season among participants with obesity p=0.024.

P-values for all other between-group comparisons within each BMI category were non-significant (smallest value p = 0.25).

Table 2. Number of valid observations and average daily minutes of wake wear time of the accelerometer at each time point by group and body mass index (BMI) category.
SD: standard deviation; T0: Baseline; T3: 3-month follow-up; T6: 6-month follow-up; T12: 12-month follow-up

		BMI 18.5-25 kg/m^2					BMI 25-30 kg/m^2					BMI ≥ 30 kg/m^2			
		Control		**Intervention**			**Control**		**Intervention**			**Control**		**Intervention**	
Wear time, min/day		**n**	**Mean (SD)**	**n**	**Mean (SD)**		**n**	**Mean (SD)**	**n**	**Mean (SD)**		**n**	**Mean (SD)**	**n**	**Mean (SD)**
T0		39	926 (52)	38	926 (64)		45	931 (51)	44	938 (42)		26	947 (41)	35	926 (51)
T3		39	924 (40)	35	938 (64)		45	935 (45)	44	948 (38)		26	953 (56)	34	948 (53)
T6		38	937 (54)	35	926 (63)		44	933 (49)	44	957 (42)		26	958 (56)	34	946 (60)
T12		39	923 (48)	35	921 (62)		43	938 (45)	44	946 (48)		26	957 (53)	34	927 (59)

Table 3. Descriptive statistics of observed average daily minutes of moderate-to-vigorous physical activity (MVPA), light physical activity (LPA) and sedentary time (SED) at each time point by group and body mass index (BMI) category.
SD: standard deviation; IQR: interquartile range; T0:baseline; T3: 3-month; T6: 6-month; T12: 12-month follow-up

	BMI 18.5-25 kg/m^2				**BMI 25-30 kg/m^2**				**BMI ≥30 kg/m^2**			
	Control		**Intervention**		**Control**		**Intervention**		**Control**		**Intervention**	
	Mean (SD)	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**
MVPA, min/day												
T0	57 (25)	56 (40–70)	67 (36)	65 (41–81)	48 (29)	46 (25–65)	58 (28)	55 (40–74)	40 (19)	39 (29–55)	47 (32)	43 (23–63)
T3	60 (28)	62 (38–72)	71 (36)	62 (49–92)	46 (32)	40 (25–56)	56 (33)	48 (36–66)	42 (27)	36 (28–51)	47 (28)	39 (29–57)
T6	58 (27)	52 (39–73)	59 (30)	65 (36–77)	46 (25)	42 (26–63)	57 (32)	49 (35–71)	39 (25)	34 (20–52)	48 (28)	50 (29–65)
T12	54 (21)	57 (40–68)	62 (28)	63 (35–81)	43 (27)	40 (26–49)	56 (31)	51 (32–75)	39 (30)	28 (23–50)	46 (32)	41 (22–67)
LPA, min/day												
T0	249 (72)	258 (188–309)	227 (73)	234 (178–274)	205 (79)	199 (158–256)	224 (70)	214 (171–268)	205 (69)	188 (152–253)	212 (71)	224 (160–261)
T3	277 (75)	267 (237–336)	241 (67)	226 (194–273)	220 (72)	212 (161–271)	232 (75)	229 (180–287)	211 (78)	197 (167–236)	230 (63)	245 (178–273)
T6	277 (70)	289 (244–318)	255 (86)	247 (193–316)	223 (75)	239 (165–266)	238 (56)	247 (197–275)	195 (69)	176 (148–238)	258 (80)	261 (203–294)
T12	253 (58)	259 (210–293)	217 (73)	210 (161–255)	211 (70)	194 (154–273)	223 (76)	223 (153–289)	195 (101)	175 (118–271)	208 (78)	217 (143–257)
SED, min/day												
T0	620 (101)	616 (532–682)	632 (109)	607 (554–706)	678 (101)	684 (623–736)	656 (91)	651 (601–731)	702 (87)	725 (647–757)	666 (87)	659 (607–715)
T3	587 (94)	575 (519–654)	626 (112)	630 (550–680)	668 (93)	673 (624–734)	660 (93)	666 (596–715)	700 (93)	701 (675–770)	671 (93)	665 (607–740)
T6	603 (97)	594 (527–672)	612 (106)	615 (522–695)	664 (94)	661 (602–711)	662 (90)	655 (598–726)	723 (77)	726 (679–775)	640 (97)	642 (591–714)
T12	616 (74)	612 (552–665)	642 (104)	650 (567–697)	684 (98)	691 (610–769)	667 (88)	678 (594–718)	723 (110)	739 (644–814)	673 (109)	670 (638–743)

Figure 1. Changes in average daily minutes of A) moderate-to-vigorous physical activity (MVPA), B) light physical activity (LPA) and C) sedentary time (SED) with observed data points among participants with obesity. Graphs present model-based means adjusted with wake wear time and baseline season and their 95% confidence intervals.

Figure 1.