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Changes in physical activity and sedentary behavior associated with an exercise intervention in depressed adults

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A B S T R A C T

Background: Exercise is beneficial for depression, but less is known about its impact on post-intervention physical activity and sedentary behavior. The aim of this paper was to determine the extent to which participation in light-, moderate- and vigorous-intensity exercise intervention influenced habitual physical activity and sedentary behavior patterns in depressed adults.

Methods: Accelerometer data was collected pre- and post-intervention from depressed participants randomized to one of three 12-week intervention groups: light ($n = 21$), moderate ($n = 25$) and vigorous ($n = 22$) exercise. Mixed models examined changes in time spent sedentary and in light and moderate-to-vigorous physical activity (MVPA); time accumulated in sedentary and MVPA bouts; and, number of MVPA bouts and interruptions in sedentary time.

Results: Overall sedentary time decreased while light activity time increased across all intervention groups but not significantly so. The light exercise intervention group reduced MVPA minutes (−8.22, 95% CI: −16.44, −0.01), time in MVPA bouts (−8.44, 95% CI: −14.27, −2.62), and number of activity bouts (−0.43, 95% CI: −0.77, −0.09). The moderate exercise intervention group reduced time in MVPA bouts (−6.27, 95% CI: −11.71, −0.82) and number of sedentary interruptions (−6.07, 95% CI: −9.30, −2.84). No changes were observed for the vigorous exercise intervention group.

Conclusions: The exercise intervention led to an increase in overall light physical activity and decrease in sedentary time, though neither change was statistically significant. Participation in the light and moderate exercise intervention groups was associated with reductions of time in MVPA bouts, but this was not evident for the vigorous exercise intervention group.

1. Introduction

Physical activity has a beneficial role in depression (Farmer et al., 1988; Harvey, Hotopf, Overland, & Mykletun, 2010; Mammen & Faulkner, 2013; Song, Lee, Baek, & Miller, 2012; Stanton, Happell, & Reaburn, 2014; Vallance et al., 2011). The findings of a systematic review conducted in 2008 suggested that physical activity is protective against depression even at low doses (Teychenne, Ball, & Salmon, 2008). According to Cochrane reviews, exercise interventions have a small to moderate effect in reducing depression compared to a placebo or a control group and can be equally effective as pharmacotherapy or psychotherapy (Cooney et al., 2013; Rimer et al., 2012), though other reviews have suggested that this effect is even larger (Ekkekakis, 2015; Rethorst, Wipfli, & Landers, 2009; Stathopoulou, Powers, Berry, Smits, & Otto, 2006). While the mechanisms for these benefits are likely to be complex, it is possible that they may include increased serotonin synthesis, hippocampal cell proliferation (Bjornebekk, Mathe, & Brene, 2005; Dunn & Jewell, 2010) reduced levels of pro-inflammatory cytokines (Eyre, Papps, & Baune, 2013), distraction, mastery and improved self-efficacy (Barbour, Edenfield, & Blumenthal, 2007).

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More recently, increased research attention has been directed at sedentary behavior – put simply, too much sitting as distinct from too little exercise – as a risk factor for several health outcomes. Self-reported sedentary time has been associated with increased risk of type 2 diabetes (Ford et al., 2010), poor health outcomes in general, such, cardiovascular disease and cancer (Thorp, Owen, Neuhaus, & Dunstan, 2011) and higher risk of premature mortality (Matthews et al., 2012). Evidence concerning the association between sedentary behavior and depression is less clear. A recent review concluded that sedentary behavior is related to an increased risk of depression (Teychenne, Ball, & Salmon, 2011), and findings from a longitudinal study suggest that both sedentary behavior (assessed as TV viewing time) and low physical activity increased risk for depression (Lucas et al., 2011).

One important research question that has not been elucidated is whether those who participate in structured exercise programs subsequently change their overall physical activity and sedentary behavior. A recent review concluded that it is possible to reduce overall sedentary behavior through structured behavioral interventions, however, the interventions that were effective specifically targeted sedentary time, or had multiple components such as physical activity and nutrition (Martin et al., 2015). To date, no studies have examined the effects on sedentary behavior of prescribed exercise interventions for depression.

A limitation of previous exercise intervention studies in depressed adults is that all used self-report measures of physical activity and sedentary behavior. More recently, objective measurement devices have been used in physical activity research. These have primarily been enabling the assessment of participation in exercise interventions on patterns of overall physical activity and sedentary behavior (including sedentary time accumulated in longer bouts and interruptions in sedentary time). Accelerometer-measured sedentary time accumulated in longer bouts, for example 20 and 30 min, were found to have deleterious associations with cardio-metabolic health (Lyden, Keadle, Staudenmayer, Braun, & Freedson, 2015), while frequently interrupting sedentary time has a more beneficial association with metabolic risk (Healy et al., 2008; Healy, Matthews, Dunstan, Winkler, & Owen, 2011). Moderate-to-vigorous physical activity and sedentary time has been associated with depression, especially in overweight and obese adults, (Vallance et al., 2011) and a higher number of objectively-assessed sedentary bouts have been found to be associated with increased depression severity (Helgadottir, Forsell, & Ekblom, 2015).

Before going further it is important to the aim of this paper to address the difference between exercise and physical activity. Physical activity is defined as all expenditure of energy through skeletal muscles while exercise is a subset of physical activity that is planned, structured, repetitive, and it's purpose is to improve fitness (Caspersen, Powell, & Christenson, 1985). Where previous studies using data from exercise interventions for depression have restricted themselves to reporting impact on depressive symptoms, occasionally reporting the level of exercise/physical activity done by the participants at the end of the study, we will try to disentangle the concepts of exercise and physical activity to see how an exercise intervention for depression might impact on the habitual levels of physical activity and sedentary behaviour. The aim of our study therefore is to examine changes in overall accelerometer-measured physical activity and sedentary behavior associated with participation in light-, moderate- and vigorous-intensity physical exercise in depressed adults, comparing baseline with follow-up after the conclusion of the intervention using a unique dataset from one of the largest community-based RCT's on the effect of exercise on depression.

2. Methods

2.1. Study design

Data were derived from the Regassa study (protocol available at regassa.se), a pragmatic, single-blind, randomized controlled trial of three parallel intervention arms for depression, conducted in six Swedish counties and regions. One of the aims of the Regassa study was to evaluate the effectiveness of three different treatments for mild-to-moderate depression (Hallgren et al., 2015). The three intervention arms were exercise, internet-based cognitive behavioral therapy and treatment as usual. The current study uses the data only from the exercise arm and as it is a sub-study of the main study no power calculations were performed for the current analysis a priori. The Regassa study was originally registered with the Karolinska Clinical Trial Registry (KCTR study ID: CT20110063) before the start of the study but as this registry has closed down the trial was re-registered at the German Clinical Trial Register (DRKS study ID: DRKS00008745).

2.2. Participants

Participant recruitment was undertaken through primary health care centers and via advertisements from the 14th of February 2011 to the 31st of January 2013. People aged 18–67 years, who scored $\geq$10 points on the Patient Health Questionnaire, corresponding to at least mild depression, were invited to participate. Exclusion criteria included insufficient understanding of Swedish, a primary diagnosis of alcohol or drug dependency or abuse, serious somatic disorders that precluded participation in exercise or was the underlying cause of depression as judged by their primary care physician, or a mental disorder requiring specialist psychiatric treatment (e.g. psychosis). Suicide risk was monitored throughout the study period and people at high risk were excluded from the trial and offered usual treatment by their physician.

Participants ($N = 310$) in the exercise arm were further randomized to three levels of exercise intensity: light, moderate and vigorous. The randomization was done by an external organization, the Karolinska Trial Alliance. The ratio of participants per group was 1:1:1. The assignment of the participants was computer generated and it was not possible to get the randomization information until all the pre-treatment measurements had been completed. Fig. 1 depicts how participants were included and excluded in the study. All participants provided a written informed consent and the study was approved by the Stockholm regional ethical review board (Dnr: 2010/1779-31/4).

2.3. Intervention

The 12-week exercise intervention was undertaken 3 times per week for approximately 55 min each occasion. For the duration of the study the participants had a free subscription to the fitness center chain. The "light" exercise classes consisted of basic yoga, stretching and balance movements (without a strong mindfulness component). The "moderate" group consisted of intermediate level aerobic exercise training. The standardized classes consisted mainly of dynamic whole body movements designed to increase heart-rate, such as light jogging and hopping exercises intermixed with isometric movements (e.g. knee bends). The "vigorous" aerobic exercise classes were more challenging with a stronger emphasis on the repetition of both static and explosive movements, such as push-ups and sit-ups, the focus being on higher intensity training. Objectively measured differences between the three exercise groups have been reported elsewhere (Helgadottir, Hallgren, Ekblom, & Forsell, 2016). Further details on how the

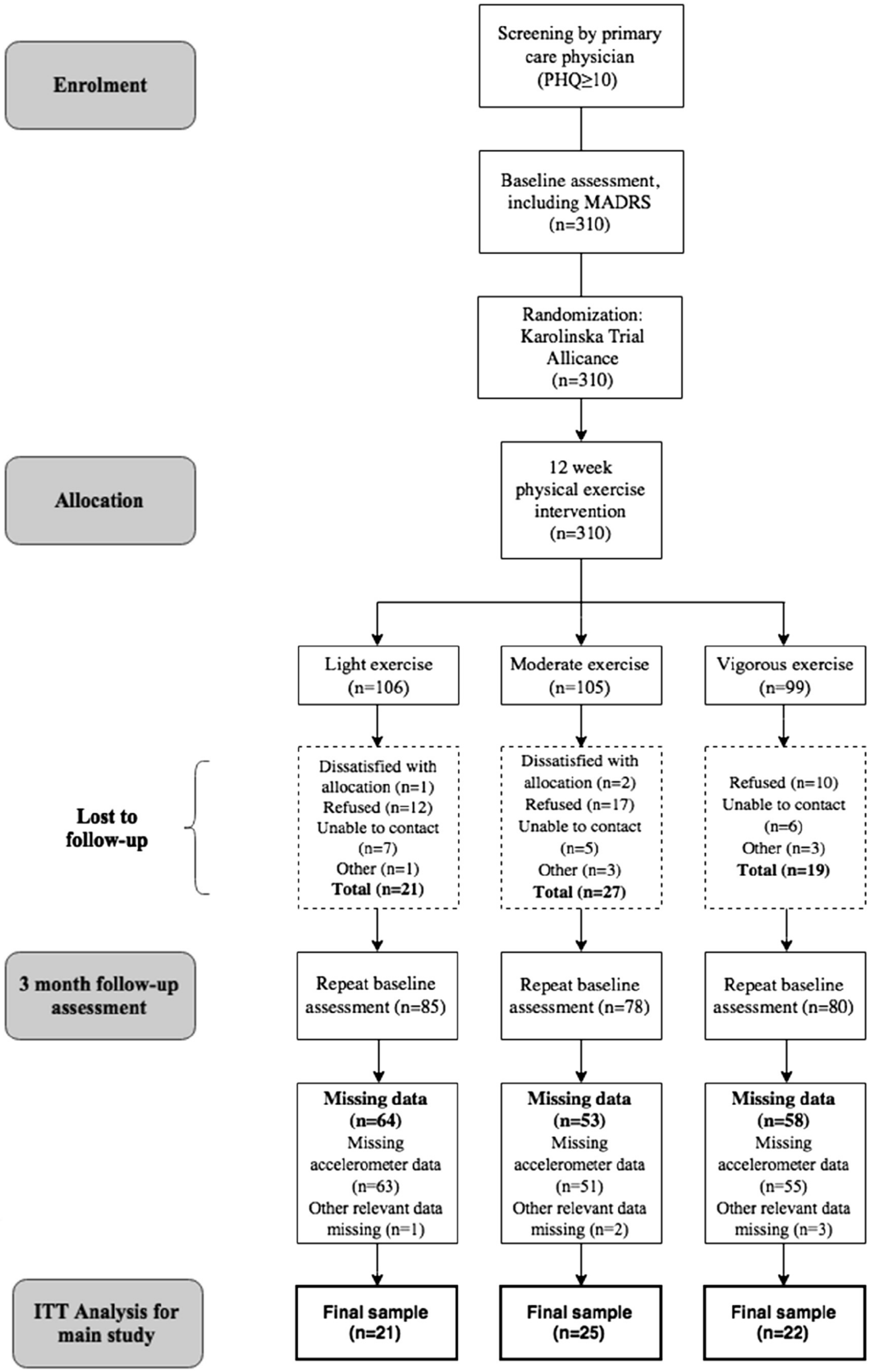

Fig. 1. Flow chart of the participants in the study.

recommended classes were selected are available in the appendix.

The participants met with a member of the study staff once a week to download data from the accelerometers and to report on the number of sessions and which classes were attended. The study staff (mainly general nurses, physiotherapists and personal trainers) could give advice about exercise but were instructed to not to discuss issues related to depression.

On average, the sample used in this current paper (described below) participated in 18.8 sessions (SD = 11.4) out of the 36 prescribed sessions; light exercise group = 21.0 sessions, moderate exercise group = 19.0 sessions, vigorous exercise group = 16.2 sessions, no statistically significant differences between groups.

2.4. Measures

Accelerometers (ActiGraph model GT3X+) were used to collect data on physical activity and sedentary behavior patterns and the ActiLife version 6.11.8 analysis software was used to summarize the data. Participants were asked to wear an accelerometer on their right hip for one week prior to the intervention (week 0) and one week after the intervention had finished (week 13). Participants were also asked to wear their accelerometers during the entire intervention (12 weeks) as originally the researchers intended to investigate trends the changes of physical activity for the duration of the intervention but due to low compliance this idea proved impractical. The participants were instructed to remove the device when engaging in water activities (showering, swimming etc.) and when attending the exercise sessions that were part of the intervention but otherwise wear it during waking hours.

The data were collected in 60 second epochs. Non-wear periods were defined as 60 consecutive minutes of no activity (0 counts), with a threshold for interruptions for 2 min of up to 200 counts. At least 600 min of monitoring were needed for a valid day and a valid week was defined as at least one weekend day and one weekday (Tudor-Locke, Camhi, & Troiano, 2012). The vast majority of the participants had at least 4 days of monitoring; 92.7% and 92.7% for the pre- and post-intervention weeks, respectively. No overlap between the accelerometer data and intervention period was permitted since the accelerometer observation had to occur pre- or post-intervention. This was possible as we had exact dates for when the exercise sessions occurred and when the accelerometer data was recorded.

A few participants stopped exercising before the scheduled end of the intervention and did not hand in any accelerometer data for the post-intervention week (week 13). For these participants, we included their last observed accelerometer week if it occurred after they had stopped participating in the exercise intervention and they had participated for at least 8 weeks. Approximately one-fifth had data from weeks 9–11, 66.2% from weeks 12–14 and 13.3% from later weeks due to delays in their intervention. Participants with valid pre- and post-intervention weeks and for whom complete relevant data were available, were included in the study (n = 68).

The large component of missing accelerometer data observed (from n = 310 to n = 68) was due to a missing pre-intervention week (n = 104), incomplete pre-intervention week (n = 34), missing post-intervention week (n = 157), incomplete post-intervention week (n = 63), and too few weeks between pre- and post-intervention (n = 20). Note that participants could belong in more than one category, i.e. have both an incomplete pre-intervention week and a missing post-intervention week and six participants were excluded due to insufficient data on other relevant variables. The participants included in the current paper were slightly older ($p = 0.009$) and attended more exercise sessions ($p < 0.001$) than the original larger sample.

Cut-offs for categorizing activity were based on the suggestions by Freedson et al. (Freedson, Melanson, & Sirard, 1998); sedentary (<100 counts/min), light physical activity (100–1951 counts/min) and moderate-to-vigorous physical activity (≥1952 counts/min). Minutes spent in sedentary, light and moderate-to-vigorous physical activity (MVPA) were standardized to 16 h days to account for difference in wear times.

Two variables represent accumulated sedentary time (<100 counts/min) in bouts of either ≥20 or ≥30 min (Lyden et al., 2015), with no interruptions allowed. Number of sedentary interruptions was defined as an interruption in sedentary time that was ≥100 counts/min, lasting for at least 1 min (Healy et al., 2008).

Accumulated MVPA time was defined as bouts of ≥10 min of ≥1952 counts/min, with allowed interruptions of <1952 counts/min for two minutes. Number of MVPA bouts was also explored.

2.5. Potential confounders

Several variables measured pre-intervention were considered as possible confounders. These included sex, age, body mass index (BMI, kg/m2, based on self-reported height and weight), education, and tobacco use (smoking or using snus daily). Number of somatic conditions or disorders was also considered as a confounder, selected from a list of eleven possible conditions that the participants stated if they had been treated for or received a diagnosis by a physician: reduced mobility, rheumatologic disorders, back, shoulder or neck pain; headache; cardiovascular disease, including high blood pressure; neurological disease; diabetes or other metabolic disease; asthma or other lung conditions; ulcer and other chronic conditions of the digestive system and the liver; diseases in kidneys, urine tract or uterus; serious infection or injury; tumor; or other serious disease. Additionally, depression severity as measured pre-intervention using the Montgomery Åsberg Depression Rating Scale (MADRS) (Montgomery & Asberg, 1979) was considered a possible confounder. The scale consists of 10 questions and was administered face-to-face by nurses. As one of the items on the MADRS is “apparent sadness” was missing for two participants, this item was imputed using another item, “reported sadness”. Finally, we considered whether seasonal change, going from winter to a warmer season or vice versa (or darker to lighter season), might affect the potential change in physical activity patterns and sedentary behavior.

2.6. Statistical analysis

All analyses were done in Stata statistical software release 12.0 (Stata College Station, TX). Figures were created in draw.io and GraphPad Prism 6. Significance level was set at $p < 0.05$ (two-tailed). Differences between the exercise intensity groups were explored using chi-square tests (categorical variables) or ANOVA (continuous variables) where appropriate.

The analysis for each outcome (standardized sedentary minutes, standardized light minutes, standardized MVPA minutes, time in sedentary bouts of ≥20 min, time in sedentary bouts of ≥30 min, number of sedentary interruptions, time in MVPA bouts of ≥10 min, and number of MVPA bouts) were performed using linear mixed models (in Stata: xtmixed) to account for the correlation between repeated measures of the same individuals over time. All models were adjusted for fixed effects of the group, pre-intervention values of the outcome (to control for possible regression to the mean), age, sex, BMI, number of weeks between pre- and post-intervention accelerometer measurements, and number of exercise sessions. No changes were observed in the results when adjusting for other potential confounders (e.g. number of somatic conditions or disorders, education, tobacco use, pre-intervention MADRS, seasonal change). All outcomes related to bouts and interruptions (time in sedentary bouts of ≥20 min, time in sedentary bouts of ≥30 min, number of sedentary interruptions, time in MVPA bouts of ≥10 min, and number of MVPA bouts) were additionally adjusted for wear time. Models did not display any problems with heteroscedasticity, nonlinearity, or non-normality. Results from all models are reported as marginal means with 95% confidence intervals.

3. Results

The mean age of the whole sample was 45.2 (SD = 11.9) years and 66.2% were women. No statistically significant differences were seen pre-intervention between the exercise intensity groups (Table 1). On average the groups spent between 618 and 647 min per day in sedentary time pre-intervention and 45.7–49.1 min in MVPA (Table A1).

Reductions in sedentary time were seen across all groups (ranging between −7.1 and −11.3 min) while increases were observed in minutes spent in light physical activity (between 6.1 and 19.0 min), though none were statistically significant (Fig. 2). MVPA time decreased significantly by 8.2 min (95% CI: −16.4, −0.01) in the light exercise intervention group, while the changes in the moderate (decrease) and vigorous (increase) exercise groups were not significant.

No significant changes were observed regarding time accumulated in either ≥20 or ≥30 min sedentary bouts (Fig. 2). Time accumulated in MVPA bouts of ≥10 min was reduced in the light exercise intervention group by 8.4 min (95% CI: −14.3, −2.6) and by 6.3 min (95% CI: −11.7, −0.8) in the moderate intervention group (Fig. 3). The vigorous intervention group had a higher average number of minutes accumulated in MVPA bouts post-intervention than the light and the moderate exercise intervention group, by 12.2 min (95% CI: 3.8, 20.6) and 10.0 min (95% CI: 1.7, 18.3), respectively, and the overall difference between groups was significant (p = 0.012).

Number of sedentary interruptions was significantly decreased in the moderate exercise intervention group by 6.1 interruptions per day (95% CI: −9.3, −2.8) while a slight increase in the light exercise intervention group (3.0 interruptions, 95% CI: −0.05, 6.4) did not quite reach statistical significance (p = 0.093). The difference between the light and the moderate exercise intervention groups was significant at post-intervention (9.0 interruptions, 95% CI: −13.8, −4.29, see Fig. 4) as well as the difference between the moderate and vigorous exercise intervention groups (5.7 interruptions, 95% CI: 0.8, 10.7). Additionally, both the light and the moderate exercise intervention groups saw small reductions in the number of MVPA bouts by 0.4 (95% CI: −0.8, −0.1) and 0.2 (95% CI: −0.6, 0.1), respectively (Fig. 3). On average, the vigorous exercise intervention group had a higher number of MVPA bouts at post-intervention compared to the light exercise intervention group, by 0.5 bouts (95% CI: 0.0, 1.0).

4. Discussion

On the whole, these findings show that participating in a structured exercise intervention increased light physical activity and decreased sedentary time as measured by accelerometry though in neither case significantly so. Participation in the light and moderate exercise intervention groups was associated with reductions in time in MVPA bouts and in the light exercise group there was also a reduction in MVPA minutes, but this pattern was not evident for the vigorous exercise intervention group. Previous studies with depressed adults (Chalder et al., 2012; Oeland, Laessoe, Olesen, & Munk-Jorgensen, 2010) have reported increases in overall physical activity after an exercise intervention. However, these findings (Chalder et al., 2012; Oeland et al., 2010) were based on self-reported rather than accelerometer-measured physical activity, which invariably makes it difficult to directly compare to our study. The increase observed in these studies could be due to a difference in the design of the intervention, an increase in light activity as we found in our study, or a consequence of the measurement not being objective: that is, participants might have felt compelled to report a change as this was the aim of the intervention.

The overall MVPA (both MVPA minutes and time in bouts) was unchanged in the vigorous exercise intervention group, but there was a trend of decreased MVPA in the light (both MVPA minutes and time in bouts) and moderate exercise groups (time in bouts only). The decrease in MVPA levels in the light- and moderate-intensity exercise groups could have been due to their behavior changing as a response to participating in a structured exercise intervention. It does not appear that this led to them being sedentary more than previously, but rather, their reduced MVPA seems to have been replaced by light physical activity.

Another explanation for the reduction in MVPA could relate to a change in the instructions given to participants. Initially, participants were instructed *not to wear* their accelerometers during the prescribed exercise sessions. During the post-treatment week, however, they were instructed to start wearing them when they exercised. It is possible that the message to wear the accelerometers at all times during the post-treatment week was not emphasized enough by the study personnel when it was time for the participants to start collecting these data. This could have led to an underestimation of MVPA in the post-treatment week and the overall increase of MVPA.

It is important to put the MVPA levels into context. At baseline the participants accumulated (on average) 46.9 min of MVPA. This number may appear high, as it exceeds the recommended daily levels of physical activity. However, guidelines from the American College of Sports Medicine (ACSM) recommend that moderate or vigorous physical activity should be accumulated in bouts of at least 10 min or more (Garber et al., 2011). Therefore the variable depicting MVPA minutes accumulated in bouts of 10 or more

Table 1
Pre-intervention characteristics of the three exercise intensity groups.

	Light exercise	Moderate exercise	Vigorous exercise	p
	n = 21	n = 25	n = 22	
Age (yr), *mean* ± *SD*	43.5 ± 10.7	45.7 ± 12.1	46.2 ± 13.2	0.729
Women, *n (%)*	15 (71.4)	16 (64.0)	14 (63.6)	0.829
BMI (kg/m^2), *mean* ± *SD*	25.4 ± 3.7	27.0 ± 4.4	25.5 ± 3.2	0.279
University education or similar, *n (%)*	10 (47.6)	8 (32.0)	7 (31.8)	0.463
Tobacco users, *n (%)*	2 (9.5)	5 (20.0)	4 (18.2)	0.600
≥2 somatic disorders, *n (%)*	6 (28.6)	4 (16.0)	4 (18.2)	0.544
Depression severity (MADRS), *mean* ± *SD*	20.1 ± 8.1	22.6 ± 5.9	20.4 ± 6.0	0.342

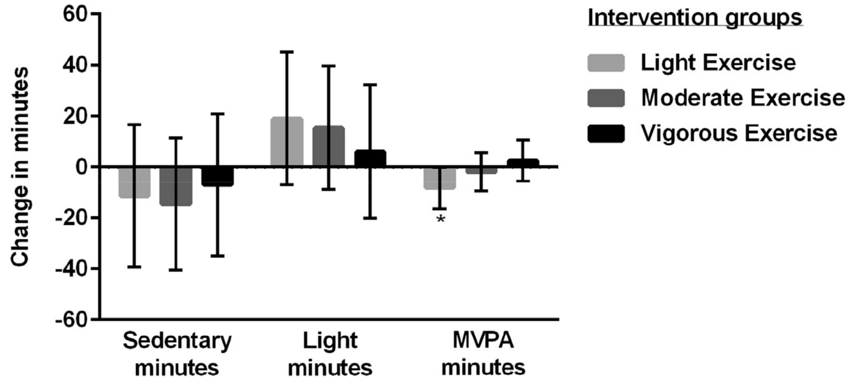

Fig. 2. Adjusted mean changes from pre-treatment to post-treatment in standardized minutes spent in sedentary, light and MVPA (*p < 0.05).

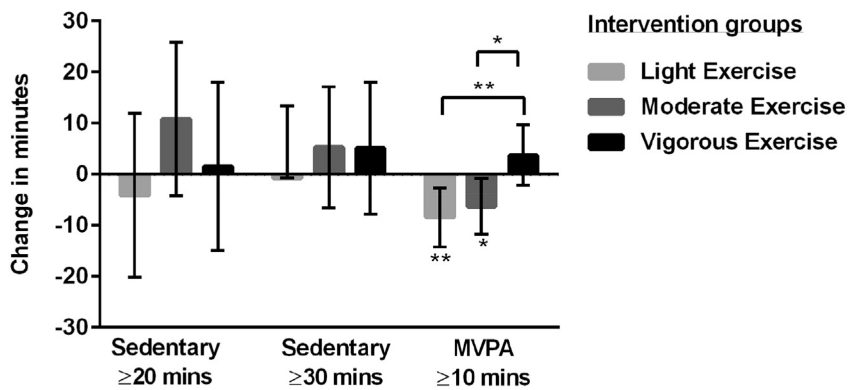

Fig. 3. Adjusted mean changes from pre-treatment to post-treatment in accumulated sedentary and MVPA bout time (*p < 0.05, **p < 0.01).

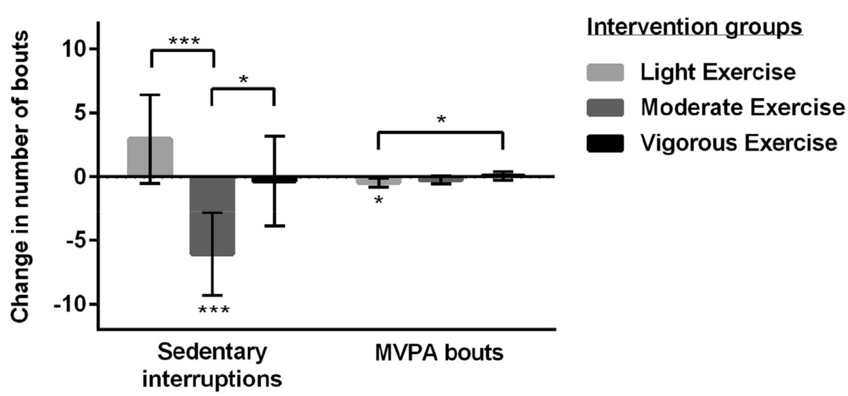

Fig. 4. Adjusted mean changes from pre-intervention to post-intervention in sedentary interruptions and MVPA bouts (*p < 0.05, ***p < 0.001).

minutes is more informative regarding adherence to these recommendations. On average, the participants accumulated 20.6 min of MVPA in bouts of 10 or more minutes, which could be a slight overestimate as we allowed a drop time of 2 min, meaning that in practice the bouts could be only 8 min in length. For a more detailed discussion of how the definition of an MVPA bout can affect fulfillment of physical activity guidelines see Hagströmer et al. (Hagstromer, Oja, & Sjostrom, 2007).

There was a tendency (albeit non-significant) for the moderate and vigorous exercise intervention groups to increase the time spent in prolonged bouts of sedentary time, especially bouts of 30 min or more. Additionally, the moderate exercise intervention group significantly decreased the number of interruptions, though the number increased in the light exercise intervention group. Evidence that these sedentary patterns have been shown to be detrimental for health indicators in general (Healy et al., 2008; Healy et al., 2011) and to depression (Helgadottir et al., 2015), suggests that such patterns should be avoided as much as possible.

The reasons for this negative impact on sedentary behavior in the moderate and vigorous exercise groups are debatable and could include avoidance of activity, due to muscle soreness or negative affect associated with high intensity exercise (Ekkekakis, Parfitt, & Petruzzello, 2011) leading to longer, uninterrupted sedentary bouts. We can only speculate and more studies are needed and future interventions in depressed people should consider targeting sedentary behavior in addition to exercise and try to disentangle the reasons for why changes in behaviors occur.

4.1. Strengths and limitations

The data for this study came from a randomized controlled trial, conducted as close to a real world setting as possible. This allowed us to examine the influence on physical activity and the sedentary behavior patterns of depressed patients as measured by accelerometer if exercise were prescribed by a physician for treating depression. Most exercise intervention studies conducted for depression do not have different levels of intensity so this was a unique opportunity to determine if changes were dependent on exercise intensity. The measurement of physical activity and sedentary time was objective, facilitating a comparison of the nuances of physical activity and sedentary behavior which questionnaires cannot accurately capture. The selection of participants from different geographic areas, varying in population density and composition was deliberate to help maximize the external validity of the findings from the Regassa study.

The sample was rather small due to insufficient data for many of the participants. On average, the participants were slightly older ($p = 0.009$) and attended more exercise sessions ($p < 0.001$) than the original larger sample, which could have led to an overestimation since our sample had a higher exposure to the intervention. We tried to limit the impact of this by adjusting for both age and number of sessions. A larger sample might have made it possible to detect differences that were not significant in our sample but as most of the non-significant changes were small, and not close to being significant, the sample would have needed be substantially larger to reach statistical significance. The larger study sample included a treatment as usual arm, but since those participants were not asked to wear accelerometers they could not be included in the analysis. Additionally, accelerometers cannot accurately measure certain types of activity such as cycling and swimming, which some of our sample might have engaged in during or after completing the intervention. We also acknowledge that accelerometers might have limitations when detecting low speed gait (Sellers, Dall, Grant, & Stansfield, 2016) and detecting transitions from sitting to standing and might therefore overestimate the number of sedentary interruptions (Barreira, Zderic, Schuna, Hamilton, & Tudor-Locke, 2015). Additionally as we standardized the wear time, the measurements of time spent in sedentary, light physical activity and MVPA are interrelated, as one goes up, another goes down.

5. Conclusions

Our findings show that, in depressed adults, participation in light-, moderate- and vigorous-intensity exercise intervention programs did not significantly alter overall light physical activity or sedentary time as measured by accelerometry. While those in the vigorous exercise intervention group tended to increase their overall MVPA (both MVPA minutes and time in bouts), there were significant reductions in MVPA for those in the light (both MVPA minutes and time in bouts) and moderate exercise intervention groups (time in bouts only). This difference could possibly be due to different behavioral adaptations to vigorous relative to light or moderate exercise, which may have had an influence on changes in MVPA. Previous studies have shown that exercise can be effective for treatment of depression (Cooney et al., 2013; Rimer et al., 2012) and the intensity of exercise might not make a difference to the magnitude of the reduction in depression severity (Helgadottir et al., 2016). Combined with this previous knowledge our results suggest that vigorous exercise can be recommended if clinically appropriate as it had no significant detrimental effect on the pattern of physical activity and sedentary behavior as measured by accelerometry. Alternatively lower exercise intensities could be chosen as long as the patient is made aware of the potential negative impact on sedentary behavior and efforts are made to counteract this effect. However more studies are necessary to explore this issue and future intervention studies on exercise for depression should consider including components on sedentary behavior or simply examine a sedentary intervention as treatment for depression. Future studies should explore the associations objectively assessed sedentary time with depression severity, to determine whether sedentary behavior plays an important role in depression and depression treatment response. Looking at functional outcomes such as work capacity and sick leave in relation to sedentary behavior would also be of interest.

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Authors' contributions

All authors were involved in the conception and design of the study. BH carried out the analysis and wrote the first draft. All authors contributed to the editing and improvement of the manuscript.

Availability of data and materials

All data are available on request from BH or YF.

Conflicts of interests

All authors declare no conflicting interests.

Table A1
Raw re-intervention values and adjusted mean changes[a] from pre-intervention to post-intervention in physical activity and sedentary behavior and adjusted differences between the groups post-intervention (results from linear mixed model analyses).

	Light exercise (SD/95% CI) $n = 22$	Moderate exercise (SD/95% CI) $n = 25$	Vigorous exercise (SD/95% CI) $n = 21$	Mean differences between the groups (95% CI)			
				Moderate - Light	*Vigorous - Light*	*Vigorous - Moderate*	*p*
Pre-intervention sedentary, *mins/16-hour* day	618 (100)	628 (89)	647 (74)				
Changes in sedentary, *mins/16-hour* day	−11.31 (-39.22, 16.61)	−14.52 (-40.49, −11.44)	−7.06 (-34.97, 20.84)	−3.21 (-41.50, 35.07)	4.25 (-35.58, 44.08)	7.46 (-31.63, 46.55)	0.932
Pre-intervention light, *mins/16-hour* day	292 (93)	286 (74)	267 (68)				
Changes in light, *mins/16-hour day*	19.00 (-7.10, 45.10)	15.36 (-8.92, 39.65)	6.09 (-20.03, 32.21)	−3.64 (-39.43, 32.16)	−12.91 (-50.18, 24.37)	−9.27 (-45.87, 27.33)	0.784
Pre-intervention MVPA, *mins/16-hour* day	49.1 (34.9)	45.7 (36.0)	46.1 (26.4)				
Changes in MVPA minutes, *mins/16-hour day*	−8.22 (-16.44, −0.01)*	−1.87 (-9.47, 5.74)	2.65 (-5.47, 10.76)	6.36 (-4.92, 17.63)	10.87 (-0.74, 22.48)	4.51 (-6.81, 15.83)	0.182
Pre-intervention time in sedentary bouts ≥20 min	52.6 (38.7)	52.5 (57.7)	38.5 (34,7)				
Changes in time in sedentary bouts ≥20 min	−4.14 (-20.18, 11,90)	10.82 (-4.25, 25.89)	1,54 (-14.92, 18.00)	14.96 (-7.03, 36.94)	5.68 (-17.73, 29.09)	−9.28 (-32.56, 14.01)	0.405
Pre-intervention time in sedentary bouts ≥30 min	28.0 (25.0)	31.1 (40.0)	19.4 (25.1)				
Changes in time in sedentary bouts ≥30 min	−0.77 (-13.38, 11.84)	5.29 (-6.59, 17.17)	5.12 (-7.82, 18.05)	6.05 (-11.28, 23.39)	5.88 (-12.49, 24.25)	−0.17 (-18.53, 18.18)	0.745
Pre-intervention number of sedentary interruptions	82.7 (16.4)	82.9 (14.5)	86.2 (16.5)				
Changes in number of sedentary interruptions	2.96 (-0.50, 6.42)	−6.07 (-9.30, −2.84)***	−0.33 (-3.84, 3.17)	−9.03 (-13.77,-4.29)***	−3.29 (-8.30, 1.71)	5.73 (0.79, 10.68)*	0.001*
Pre-intervention time accumulated in MVPA bouts ≥10 min	22.1 (19.0)	19.9 (24.7)	20.0 (17.1)				
Changes in time accumulated in MVPA bouts ≥10 min	−8.44 (-14.27, −2.62)**	−6.27 (-11.71, −0.82)*	3.74 (-2.18, 9.65)	2.18 (-5.81, 10.16)	12.18 (3.75, 20.61)**	10.00 (1.67, 18.33)*	0.012*
Pre-intervention number of MVPA bouts ≥10 min	1.30 (1.08)	1.05 (1.20)	1.25 (0.91)				
Changes in number of MVPA bouts ≥10 min	−0.43 (-0.77, −0.09)*	−0.24 (-0.56, 0.07)	0.09 (-0.24, 0.44)	0.19 (-0.28, 0.65)	0.52 (0.03, 1.01)*	0.34 (-0.15, 0.82)	0.107

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
[a] Mean change from pre-intervention (95% Confidence Interval), adjusted for pre-intervention values of age, sex, BMI and number of weeks between pre- and post-intervention accelerometer measurements and number of exercise sessions.

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Appendix 1

Originally the research team proposed and validated three exercise classes consisting of light, moderate and vigorous intensity using a portable VO^2 measurement device (Oxycon Mobile, Intramedic, Sollentuna, Sweden) and heart rate monitor (Polar RS400). The classes were originally planned to be offered at patient health care centers or nearby facilities. On further consideration, this plan was deemed impractical. Instead, members of the research team attended classes at a fitness center chain which has branches located throughout Sweden. Data was collected on multiple types of exercise classes being offered using heart rate monitors and VO^2 measurement devices and compared to the measurements collected from the "designed" exercise classes. Based on these observations three recommended classes were selected to correspond to each intensity level.

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