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EXPERIMENTALLY INVESTIGATING THE JOINT EFFECTS OF PHYSICAL ACTIVITY
AND SEDENTARY BEHAVIOR ON DEPRESSION: A RANDOMIZED CONTROLLED
TRIAL

A Thesis

Presented for the

Master of Science

Degree

The University of Mississippi

by

Jeremiah Blough

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ABSTRACT

Objective: To experimentally examine whether increasing sedentary behavior, among a young adult active population, for one week is still associated with increased depression symptomology even when allowing for a moderate engagement in physical activity (PA). **Methods:** Participants were confirmed as active via self-report and accelerometry during baseline and randomly assigned to one of three experimental groups. The Sedentary Intervention Group (n=19) reduced steps to less than 5000/day and were not allowed to exercise for one-week; the Reduced MVPA (moderate-to-vigorous PA) Group (n=18) reduced steps to less than 5000/day but exercised for 50% of their previously reported vigorous PA for one-week; and the Control Group (n=20) maintained normal activity for one-week. PA and depression levels were assessed at baseline, postintervention, and after one week of resumed normal activity for the intervention groups.

Results: The experiment was successful in altering physical activity levels among the intervention groups and maintaining activity habits in the control group ($F_{\text{Interaction}} = 16.053$, $P < 0.001$, $\eta^2_p = 0.391$). Depression symptomology remained constant across the two time periods in the control group. For both intervention groups (Sedentary Group and Reduced MVPA Group), depression statistically significantly increased during the inactive week and then resumed back to baseline levels after a week of resumed activity. However, there were no differential trends in depression ($F_{\text{Interaction}} = 0.276$, $P = 0.760$, $\eta^2_p = 0.008$) among these two intervention groups.

Conclusion: We provide experimental evidence that increasing sedentary behavior causes an

increase in depression symptomology among young active adults. We did not, however, observe a joint effect of sedentary behavior and exercise on changes in depression.

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CHAPTER I
BACKGROUND
EXERCISE AND DEPRESSION: BRIEF OVERVIEW

Depression has commonly been treated with pharmaceutical medications. However, prospective research has demonstrated that exercise creates a preventative effect against depression symptomology.

A review done by Mammen and Faulkner evaluated 30 prospective studies that analyzed the effect of physical activity on preventing depression (Mammen & Faulkner, 2013). They found that people who met physical activity guidelines at baseline had a 19-27% reduced risk of suffering from future depression symptomology (Mammen & Faulkner, 2013). Out of these 30 studies 11 of them looked at changes in physical activity, and 9 of the 11 found that increasing physical activity over time was associated with a reduced risk of depression (Mammen & Faulkner, 2013).

One of those 9 studies was done by Brown et. al and analyzed how physical activity affected depression symptomology (Brown, Ford, Burton, Marshall, & Dobson, 2005). The prospective data was from middle-aged women who were involved in the Australian Longitudinal Study on Women's Health (Brown et al., 2005). Their data found that women who increased their physical activity over time had decreased depression symptoms, and the greater the increase in activity, the greater the reduced risk of depression (Brown et al., 2005).

In addition to having a preventative effect, exercise has also been shown to be an effective treatment form for reducing depression symptomology. A meta-analysis done by Schuch et. al looked at the effectiveness of exercise as a treatment for depression (Felipe B Schuch et al., 2016). This review included 25 randomized controlled trials each involving a non-active control group and an exercise therapy group (Felipe B Schuch et al., 2016). On average, the data favored the exercise therapy as the more beneficial treatment for reducing depression symptomology among the participants (Felipe B Schuch et al., 2016).

One of the randomized controlled trials included in the meta-analysis, was another study by Schuch et. al. that looked at how exercise in addition to usual care effected depression symptoms among majorly depressed inpatients (Schuch et al., 2015). They found the addition of exercise beneficial to the reducing of depression among the severely depressed inpatients (Schuch et al., 2015).

The possible mechanisms for the antidepressant effect of exercise are commonly separated into two categories: physiological and psychological. Physiologically, exercise effects metabolism and hormones such as beta-endorphins, serotonin, endocannabinoids, and brain-derived neurotrophic factor (Schuch et al., 2015). All these are vital to maintaining homeostasis throughout the body and when changed to healthier levels by exercise, can contribute to increased health and decreased depression (Schuch et al., 2015). Exercise can improve sleep quality which may have led to reduced depression symptoms (Schuch et al., 2015).

Sleep also falls under the psychological category as it effects one's mental state if inadequate. Another possible psychological factor is a boost of self-esteem that is often a result of improving physical fitness (Schuch et al., 2015). Also, some individuals may control stress through exercise. Some people may practice participating in group fitness activities which

deepens social community and aiding in the reduction of depression symptomology (Edwards & Loprinzi, 2016). The motivation and accountability of an exercise partner helps provide physiological stability and reduces loneliness (Edwards & Loprinzi, 2016).

CHAPTER II

INTRODUCTION

Approximately 25% of adults in the United States are affected by mental illness every year (Bagalman & Cornell, 2018). Depression is one of the more prominent mental illnesses with a lifetime prevalence rate of 16.2% (Kessler, Berglund, Demler, & et al., 2003). Depression can negatively impact many aspects of an individual's life (e.g., personal relationships, academic and work performance) (Bruffaerts et al., 2012).

The traditional methods for treating depression are commonly through psychotherapy and pharmacotherapy. These methods have been shown to be effective forms of treatment (Cuijpers, van Straten, Andersson, & van Oppen, 2008; Gartlehner et al., 2016). Notwithstanding, these methods are not always cost effective and medications can have unpleasant side effects (Coplan, Aaronson, Panthangi, & Kim, 2015). However, evidence demonstrates that physical activity, which may have few sides effects and is cost-effective, has both preventative and treatment effects on this disorder (Kvam, Kleppe, Nordhus, & Hovland, 2016; Mammen & Faulkner, 2013; Mikkelsen, Stojanovska, Polenakovic, Bosevski, & Apostolopoulos, 2017; Rebar et al., 2015; F. B. Schuch et al., 2016; Felipe B Schuch et al., 2016; Ströhle, 2009; Wegner et al., 2014).

There are many proposed mechanisms for the beneficial effects of physical activity, both psychologically and physiologically. A few possible psychological mechanisms for the anti-depressive effect of physical activity include enhancing self-esteem or self-concept through, for example, social facilitation (Ekkekakis, 2013). Further, physical activity may serve as a

distraction from an individual's depression, and may boost an individual's self-efficacy allowing them to perceive more control over aspects of life leading to reduced depression symptomology (Ekkekakis, 2013). A possible physiological mechanism is that exercise increases brain-derived neurotrophic factor (BDNF), which is vital for synaptic plasticity (Ekkekakis, 2013), and thus, plays an important role in regulating the neural circuitry of mood and cognitive function (Duman, Aghajanian, Sanacora, & Krystal, 2016).

In contrast to these beneficial effects of physical activity, sedentary behavior has been shown to have deleterious effects on psychological wellbeing, independent of physical activity levels (Proper, Singh, Van Mechelen, & Chinapaw, 2011). Sedentary behavior is linked with increases in depression symptomology (Paul D Loprinzi & Sng, 2016; Zhai, Zhang, & Zhang, 2015). The majority of the research examining the association of sedentary behavior and psychological health is from an observational point of view. Few studies on this topic have investigated sedentary behavior experimentally.

To gain more experimental evidence on sedentary behavior, we recently recruited physically active individuals (≥ 150 min/week of moderate-to-vigorous physical activity [MVPA]) to participate in a one week sedentary-inducing intervention trial (Edwards & Loprinzi, 2016). We found that both depression levels increased when transitioning from an active state to a sedentary state (Edwards & Loprinzi, 2016). We also demonstrated that the depression scores returned back to baseline after one week of resuming normal physical activity levels (Edwards & Loprinzi, 2016).

The purpose of this study was to extend our previous work by experimentally examining whether increasing sedentary behavior is still associated with increased depression symptomology even when allowing for a moderate degree of engagement in physical activity

(i.e., 50% of their baseline habitual levels). This potential experimental interaction effect of physical activity and sedentary behavior on health aligns with recent observational research from our group as well as others (Ekelund et al., 2016; P. D. Loprinzi, Edwards, Sng, & Addoh, 2016; P. D. Loprinzi, Loenneke, Ahmed, & Blaha, 2016). However, such a potential interaction effect has not been examined experimentally, which was the primary purpose of the present experiment. We hypothesized that, as noted previously (Edwards & Loprinzi, 2016), an induction of sedentary behavior would cause an increase in depression symptomology, but this increase would be attenuated by a moderate degree of exercise engagement.

CHAPTER III

METHODOLOGY

Study Design

A randomized controlled trial was employed, consisting of 3 interventions arms, including a Sedentary Intervention Group (Group 1), a Reduced MVPA Group (Group 2), and a Control Group (Group 3). Procedures adhered to the 2010 CONSORT guidelines except for #24 (prospective registration of the trial). All study procedures were approved by the authors' institutional review board and consent was obtained from all participants prior to data collection.

Eligibility Criteria

Participants were eligible for participation if they were aged 18-35 years, sufficiently active by meeting physical activity guidelines (defined hereafter), did not report severe depression (i.e., PHQ-9 > 20), and had not been diagnosed with a psychological disorder within the past 6 months of the baseline assessment.

Participants

The sample involved 57 participants in total with 19 in Group 1, 18 in Group 2, and 20 in Group 3. The sample size was selected as it was similar to our previous experimental research (employing an *a-priori* power analysis) on this paradigm (Edwards & Loprinzi, 2016). See Appendix A for a flow diagram of the participant enrollment.

Recruitment

The participants were students recruited by a convenience-based sampling approach (e.g., classroom announcement at the authors' University). Recruitment began in February of 2017 and ended in November of 2017.

Study Procedures

The intervention groups (Group 1 and Group 2) participated in 4 visits and the control (Group 3) completed 3 visits, with all visits occurring 1 week apart and at approximately the same time of day. All visits were conducted in the Exercise Psychology Laboratory at the University of Mississippi. See Appendix B for a schematic of the temporal procedures of the present experiment. These temporal procedures are also detailed in the narrative that follows.

Baseline Physical Activity Eligibility Assessment

At the first visit (Baseline), physical activity was subjectively assessed via the two-item PAVS (Physical Activity Vital Sign) questionnaire (described below). Participants were eligible for participation if they were initially sufficiently active (based on self-report), defined as ≥ 150 minutes of MPA (Moderate Physical Activity) and/or ≥ 75 minutes of VPA (Vigorous Physical Activity). If eligible based on self-report, an accelerometer was given to be worn (at the midaxillary line on the right hip at the level of the iliac crest) until the next visit one week later. For the following visit (Visit 1), the accelerometer data was analyzed, and the participant continued in the study if he/she was deemed active (≥ 150 minutes of MVPA) per the accelerometry data (details on accelerometer data reduction are noted below).

Pre-Intervention Assessment

After the one-week of accelerometry assessment to confirm that participants were sufficiently active, they re-completed the PAVS questionnaire as well as a depression (PHQ-9) questionnaire. After these assessments, participants were given an accelerometer (again) and a pedometer and randomly assigned to a group via a computer-generated random sequence algorithm. Allocation of the grouping sequence was concealed and the participants were blinded to their group assignment until the end of the first visit. If assigned to the Sedentary Intervention Group (Group 1), the instructions for the following week were to not exercise whatsoever and to reduce daily steps to less than 5000, hence the pedometer. Participants were only included in the Reduced MVPA Group (Group 2) if 75 minutes or more of VPA was reported via the PAVS at Visit 1. If assigned to Group 2, the instructions for the intervention week were to only exercise at 50% of his/her reported VPA from the PAVS at Visit 1 (e.g., 90 min VPA reported, thus, 45 min prescribed vigorous exercise) and to also reduce daily steps below 5000. Participants in the Control Group (Group 3) were instructed to continue normal activity for the following week.

Post-Intervention Assessment

The next visit (Visit 2) consisted of a re-assessment of depression. The Control Group finished the study at this time. However, the intervention groups (Group 1 and Group 2) were given another accelerometer and pedometer and instructed to return to their normal physical activity patterns. Thus, all exercise restrictions were lifted for this final week. At the final visit for the intervention groups (Visit 3), the same measures were conducted and the study was then complete for Group 1 and Group 2.

Measures

Physical Activity

Subjective assessment of physical activity was assessed using the PAVS, indicating the number of minutes per week engaged in MVPA. This assessment has demonstrated evidence of validity.(Ball et al., 2015; Ball, Joy, Gren, Cunningham, & Shaw, 2016; Ball, Joy, Gren, & Shaw, 2016; Fowles, O'Brien, Wojcik, d'Entremont, & Shields, 2017; Greenwood, Joy, & Stanford, 2010) Notably, this self-report MVPA measure correlates with accelerometer-assessed number of days \geq 30 bout-min MVPA ($r=0.52$, $P<0.001$). (Ball et al., 2015)

Physical activity was objectively measured using the ActiGraph GT9X Link accelerometer which has been shown to be reliable and valid.(Kelly et al., 2013; McClain, Sisson, & Tudor-Locke, 2007) The accelerometer was worn at the midaxillary line on the right hip at the level of the iliac crest. Ten hours of wear time constituted a valid day. Sedentary behavior was defined as 0-99 counts per minute (cpm),(Matthews et al., 2008) with MVPA defined as least 1952 cpm.(Freedson, Melanson, & Sirard, 1998) Non-wear was defined as 60 minutes or more of zero activity counts, with a 1-2 minute tolerance interval.(Troiano et al., 2008) For participant awareness of their steps during the intervention, participants wore (hip) a Digi-Walker SW-200 pedometer, which has shown evidence of reliability and validity in comparison with other pedometers.(Schneider, Crouter, Lukajic, & Bassett, 2003)

Depression

Depression levels were assessed using the Patient Health Questionnaire-9 (PHQ-9). This self-report questionnaire asks participants to answer, "Over the last two weeks, how often have

you been bothered by any of the following problems?” for the following 9 items (e.g. little interest or pleasure in doing things). However, this question was altered to read “Over the last week...” to accommodate for the 1-week time period between visits, which is identical to our previous experimental work.(Edwards & Loprinzi, 2016) The response options ranged from “not at all” to “nearly every day” with respective numerical values ranging 0 to 3. Thus, the possible aggregate score ranged from 0 to 27, with higher scores indicating worse depression symptomology. This questionnaire has been used in previous research for assessing depression symptomology and has been shown to be a reliable and valid measure of depression levels.(Kroenke, Spitzer, & Williams, 2001) The PHQ-9 has shown convergent validity related to the Beck Depression Inventory ($r = 0.73$) and the General Health Questionnaire-12 ($r = 0.59$)(Martin, Rief, Klaiberg, & Braehler, 2006) as well as an internal consistency of $\alpha = 0.76$.(Bhana, Rathod, Selohilwe, Kathree, & Petersen, 2015) See Table 1 (Appendix C) for the internal consistency PHQ-9 values for the present sample. Adequate internal consistency was determined at nearly all time points.

Statistical Analysis

Statistical Analyses were computed using SPSS (version 22.0) software. Repeated measures analysis of variance (RM-ANOVA) were conducted for all measures. Based on the comparisons, either a 3 (time) x 2 (group) RM-ANOVA or a 2 (time) x 3 (group) RM-ANOVA was computed for PHQ-9, accelerometer derived daily steps, and accelerometer derived daily MVPA. A 4 (time) x 2 (group) RM-ANOVA was computed for daily MVPA via the PAVS. Effect size was calculated using Partial Eta Square (η^2_p). Statistical significance was set at a two-tailed nominal α of 0.05.

CHAPTER IV

RESULTS

Table 2 (Appendix C) displays the demographic characteristics for each of the 3 groups. There were no statistically significant differences between the groups at baseline. The entire sample (N=57) had a mean age of 20.63 ± 1.40 years and a mean BMI of 24.63 ± 3.48 kg/m². The sample included 70.2% being female and 82.5% being non-Hispanic White. All participants had completed at least some college.

Figure 1 (Appendix D) displays the mean changes in daily accelerometer-derived steps across the time points for each group. The intervention groups (Group 1 and Group 2) decreased their mean daily steps from Visit 1 to Visit 2 then increased back to near baseline at Visit 3. The mean daily steps for the Control Group (Group 3) were similar at both time points. The 2 (group) x 3 (time) RM-ANOVA showed a statistically significant main effect for time for the mean daily steps ($F_{\text{Time}} = 35.72$, $P < 0.001$, $\eta^2_p = 0.56$). For the 3 (group) x 2 (time) RM-ANOVA, there was a statistically significant main effect for time ($F_{\text{Time}} = 33.86$, $P < 0.001$, $\eta^2_p = 0.40$) as well as a statistically significant group x time interaction effect ($F_{\text{Interaction}} = 16.05$, $P < 0.001$, $\eta^2_p = 0.39$).

Figure 2 (Appendix D) displays the mean changes in daily accelerometer-derived MVPA across the time points for each group. The trend for the intervention groups (Group 1 and Group 2) was similar to Figure 1 (i.e., steps), with the mean daily MVPA decreasing from Visit 1 to Visit 2 and then increased back to baseline levels at Visit 3. The mean daily MVPA for the Control Group (Group 3) were similar at both time points. The 2 (group) x 3 (time) RM-

ANOVA showed a statistically significant main effect for time for the mean daily MVPA ($F_{\text{Time}} = 17.02, P < 0.001, \eta^2_p = 0.38$). The 3 (group) x 2 (time) RM-ANOVA showed statistically significant main effect for time ($F_{\text{Time}} = 11.548, P = 0.001, \eta^2_p = 0.18$), in addition to a statistically significant group x time interaction effect ($F_{\text{Interaction}} = 5.31, P = 0.008, \eta^2_p = 0.17$).

Figure 3 (Appendix D) displays the mean changes in weekly MVPA via the PAVS assessment across all time points (with Visit 0 signifying the baseline physical activity eligibility assessment) for the two intervention groups (Groups 1 and 2). Both groups displayed the same general trend of self-reported MVPA, decreasing from baseline through the intervention, then increasing towards normal post-intervention. However, the decrease in MVPA during the intervention week is much greater for the Sedentary Intervention group compared to the Reduced MVPA group which maintained a mean value of 72.8 ± 51.8 minutes of MVPA weekly. The 2 (group) x 4 (time) RM-ANOVA showed a statistically significant main effect for time ($F_{\text{Time}} = 58.06, P < 0.001, \eta^2_p = 0.63$) as well as a statistically significant group x time interaction effect ($F_{\text{Interaction}} = 3.41, P = 0.02, \eta^2_p = 0.09$).

Figure 4 (Appendix D) displays the mean changes in PHQ-9 scores for each group across the time points. The intervention groups (Groups 1 and 2) showed a parallel trend by scores increasing from Visit 1 to Visit 2 then decreasing back to and even below baseline scores at Visit 3. The scores for the Control Group (Group 3) remained unchanged across the 2 time points. For the 2 (group) x 3 (time) RM-ANOVA, there was a statistically significant main effect for time on the PHQ-9 scores ($F_{\text{Time}} = 7.86, P = 0.001, \eta^2_p = 0.19$), but there was no significant group x time interaction effect ($F_{\text{Interaction}} = 0.28, P = 0.76, \eta^2_p = 0.008$). The 3 (group) x 2 (time) RM-ANOVA showed that there was a statistically significant main effect for time on the PHQ-9 scores ($F_{\text{Time}} = 6.07, P = 0.017, \eta^2_p = 0.10$) as well, yet a significant group x time interaction effect was not

present ($F_{\text{Interaction}} = 1.49$, $P = 0.23$, $\eta^2_p = 0.05$).

CHAPTER V

DISCUSSION

We have recently demonstrated that experimentally increasing sedentary behavior increases depression symptomology (Edwards & Loprinzi, 2016). Following the resumption of normal physical activity in our previous experiments, the participants' depression levels returned to baseline (Edwards & Loprinzi, 2016). The present experiment replicates these findings. We desired to expand on this prior experimental evidence by investigating if increasing sedentary behavior would still be associated with increased depression symptomology even with the allowance of a moderate amount of physical activity engagement. Our hypothesis was that this abridged engagement in physical activity would attenuate the increased depression effects of increased sedentary behavior (Edwards & Loprinzi, 2016), but would not abolish the effects entirely. However, and in contrast to our hypothesis, our principle finding was that there was no attenuation of depression symptomology in the Reduced MVPA Group (Group 2). Both intervention groups (Groups 1 and 2) saw a significant increase in depression scores at the end of the intervention period. When normal physical activity was resumed, depression levels returned to baseline levels for both intervention groups. The Control Group had no significant changes in depression.

A recent review (2017) found that symptoms of depression were elevated along with other negative aspects of mental health after periods of exercise withdrawal among regular exercisers (Weinstein, Koehmstedt, & Kop, 2017). The studies that saw significant increases in

depression symptomology involved periods of exercise withdrawal or cessation ranging from 3 days to 6 weeks (Weinstein et al., 2017). Not all of these studies utilized an exercise control group and only a few measured depression levels after resuming normal physical activity levels (Weinstein et al., 2017). Another recent review (2018) agreed with the aforementioned review in that exercise cessation significantly increased depression symptomology (Morgan, Olagunju, Corrigan, & Baune, 2018). The 6 studies reported in this most recent review (2018) were included in the 8 studies analyzing depression symptomology in the previously mentioned 2017 review (Morgan et al., 2018; Weinstein et al., 2017). Few of these studies looked specifically at young adults, college aged sample (Morgan et al., 2018; Weinstein et al., 2017) which is an important sample to study as it is a transitional period with increased depression (Beiter et al., 2015). The majority of these studies did not objectively measure physical activity via accelerometry, nor did many utilize a control group and none examined the joint effects of MVPA and sedentary behavior on psychological outcomes (Morgan et al., 2018; Weinstein et al., 2017). Thus, the present experiment extends our recent studies. The findings of our current study also align with findings from our previous work (Edwards & Loprinzi, 2016). Both our previous and current experimental work demonstrated significant increases in depression symptomology among the intervention groups following a one week sedentary-inducing trial (Edwards & Loprinzi, 2016). Each experiment also demonstrated that symptomology levels returned to baseline after one week of normal physical activity (Edwards & Loprinzi, 2016). The current study saw no attenuation in depression symptomology when allowing one group of participants to engage in a moderate amount (albeit reduced from their habitual amount of exercise) of physical activity during the intervention week.

The implications of our current research suggest that even just one week of increased

sedentary behavior can increase depression symptomology among an active, young-adult population. This may be important for athletes or general daily exercisers who may suffer an injury and hamper their preferred form of physical activity. Our findings also have important implications for individuals to develop and implement relapse prevention strategies to help maintain habitual engagement of physical activity. Our results emphasize that even engaging in a reduced amount of physical activity (in this case, specifically a 50% reduction) may not be enough to stave off the negative side effects of sedentary behavior regarding depression. Another implication of this work is that the adverse results of increased sedentary behavior were negated after a week of returning to normal physical activity. Thus, if a lapse in physical activity occurs, our research points to the importance of returning to normal physical activity levels as quickly as possible. This finding highlights the importance of teaching individuals about the difference between a lapse and a relapse.

A strength of this study is that it is a novel topic using an experimental design to manipulate sedentary behavior in addition to being an extension of previous work done by our group (Edwards & Loprinzi, 2016). Another strength of our study was that we measured physical activity subjectively and objectively using accelerometry. A limitation of this study was that we utilized a nonprobability convenience-based sampling approach. However, a random sample strategy was not sensible as, per our evaluated paradigm, it was important to purposively sample physically active participants. Further, our sample population was young adults, thus, lacking generalizability to other populations, including older adults. To address these limitations, future work should consider evaluating this paradigm in other populations. Such work should also consider adding in another group that has participants engage in a forced exercise protocol in the laboratory, which contrasts with our Reduced MVPA Group that engaged in their reduced

exercise behavior in a setting of their choosing. We intentionally did this to ensure that their exercise had the potential elicit a positive affective response. Such a forced exercise protocol in the laboratory may help to avoid potential issues with exercise compliance. This could be one possible reason for why we did not observe a significant group x time interaction effect.

Although the Reduced MVPA Group still engaged in more exercise than the Sedentary Intervention Group during the week of reduced activity, not all participants were completely compliant with the instructed 50% reduced protocol. However, we computed sensitivity analyses to evaluate whether compliance (defined by us as achieving 80% (Group, 1980)] of the targeted goal) played any moderating role. Our moderational analysis included a one-way RM-ANOVA just among the Reduced MVPA Group with the grouping variable being “compliant” vs. “non-compliant” and we looked to see if there was a group x time interaction. Notably, such sensitivity analyses did not demonstrate any moderational role of exercise compliance (data not shown), suggesting that compliance to the Reduced Group protocol was likely not responsible for the non-attenuation effect of sedentary-induced depression symptomology.

In conclusion, we observed that a one week sedentary-inducing intervention trial produced increased depression symptomology which was not attenuated by engaging in approximately 50% of the participant’s habitual exercise behavior. This increase in depression symptomology dissipated after returning to normal levels of physical activity for one week. Future research should investigate these effects of sedentary behavior in other populations to evaluate the generalizability of our findings. Other work should also consider examining other levels of reduced MVPA (e.g., 25% reduction instead of 50%). Further, if our findings (i.e., that reduced MVPA does not attenuate changes in depression) are replicated, future work should consider identifying possible candidate mechanisms for such an effect. Possible mediators

include, for example, alterations in identity stabilization, cognitive dysregulation (e.g., alterations in cognitive attention), and body image perceptual change.

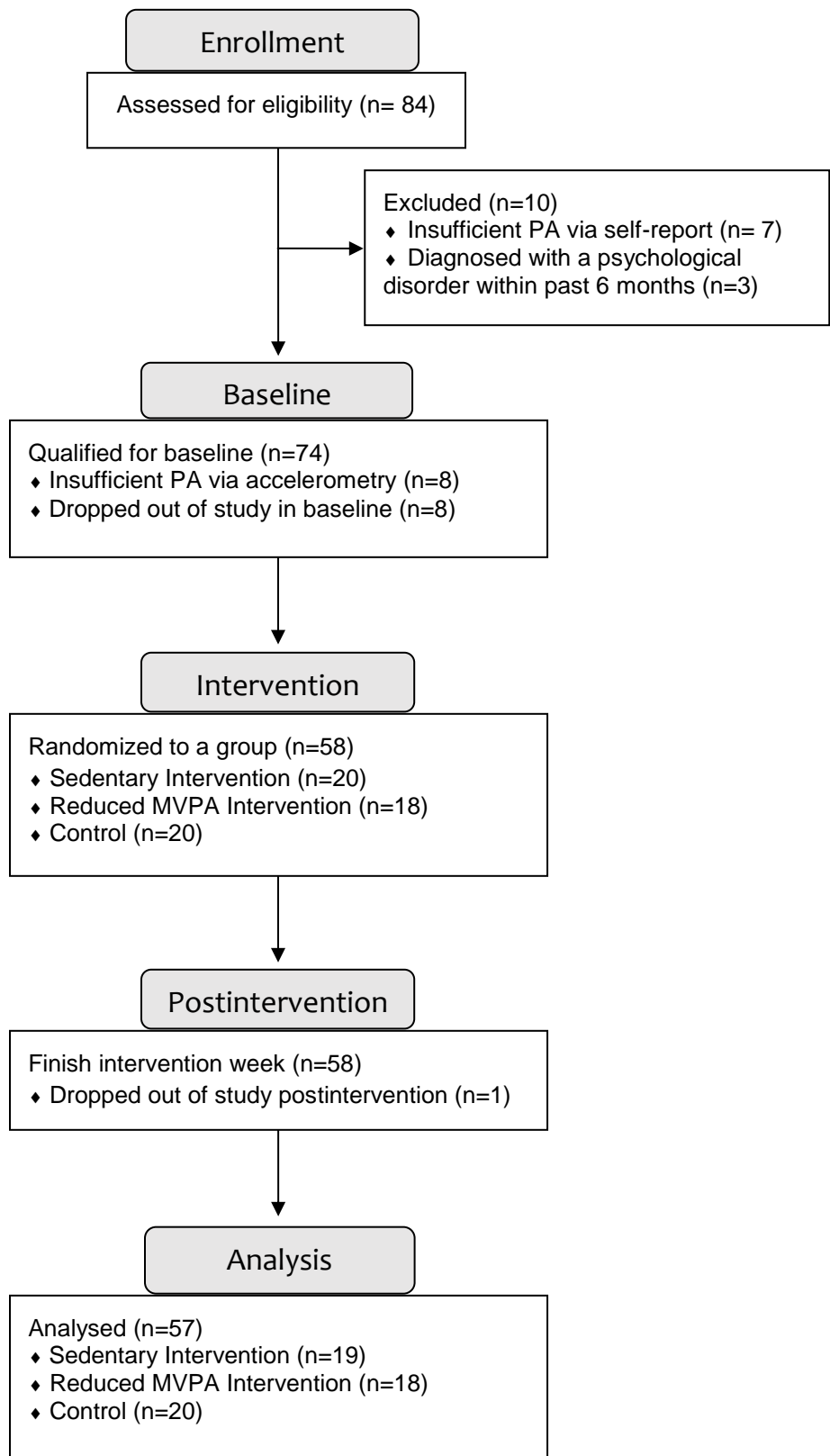
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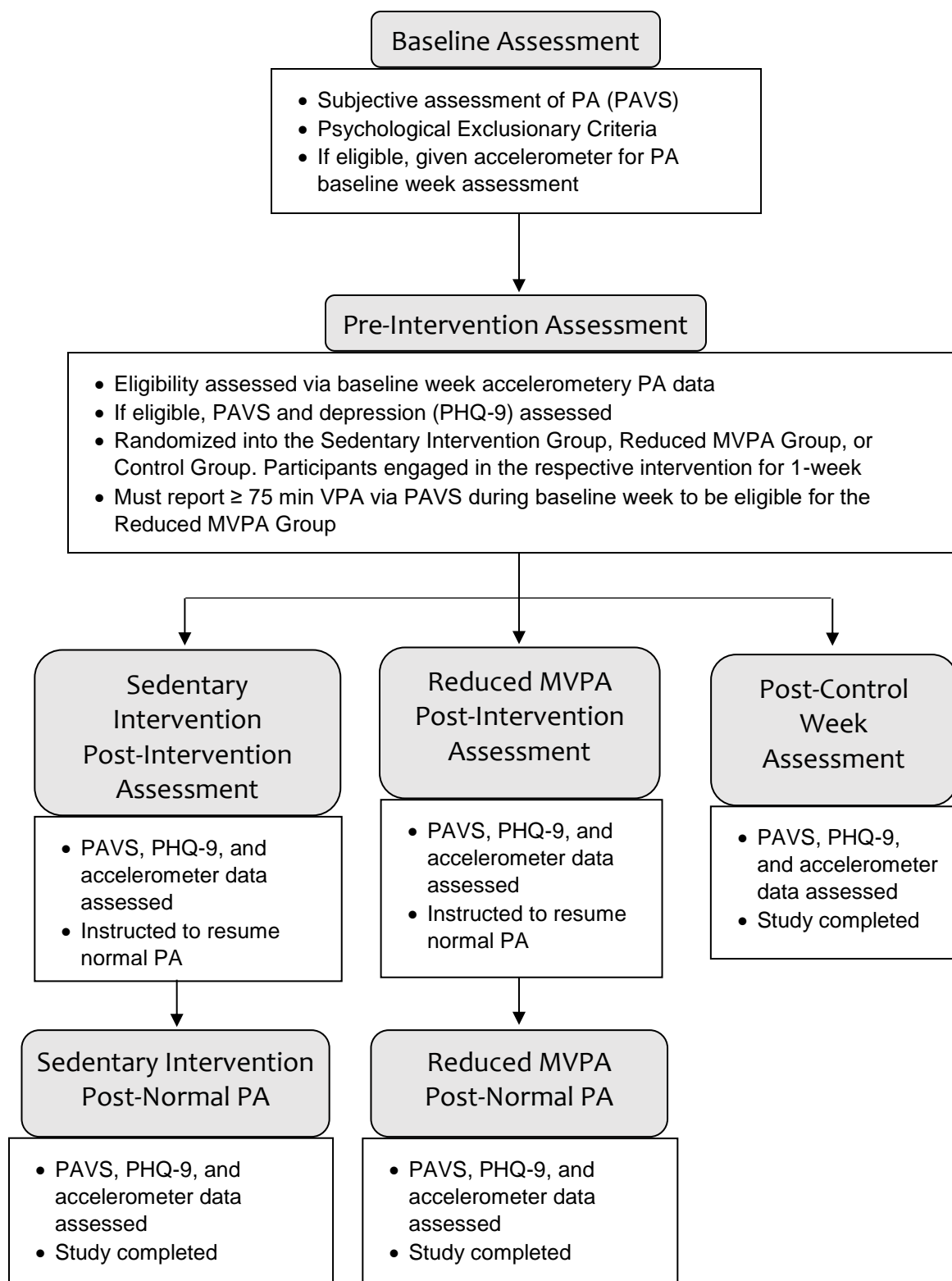
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APPENDIX



Appendix A. Participant flowchart.



Appendix B. Schematic of study procedures.

Appendix C: List of Tables

Table 1. Cronbach's Alpha values for assessing internal consistency for OASIS and PHQ-9 assessments.

Outcome	Cronbach's Alpha value for each group		
	Group 1 (Sedentary Intervention)	Group 2 (Reduced MVPA Intervention)	Group 3 (Control)
PHQ-9			
Visit 1	.848	.703	.714
Visit 2	.783	.769	.746
Visit 3	.815	.628	N/A
OASIS			
Visit 1	.788	.535	.884
Visit 2	.865	.751	.859
Visit 3	.767	.769	N/A

Table 2. Characteristics of the analyzed sample (proportion/mean \pm sd)

Variable	Group 1 (Sedentary Intervention)	Group 2 (Reduced MVPA Intervention)	Group 3 (Control)
N	19	18	20
Age, mean years	21.0 \pm 1.5	20.6 \pm 1.0	20.4 \pm 1.6
Gender, % male	31.6	22.2	35.0
Race-Ethnicity, %			
Non-Hispanic White (n=47)	84.2	83.3	80.0
Non-Hispanic Black (n=5)	10.5	5.6	10.0
Other Hispanic (n=1)	5.3	0	0
Other/Multi-race (n=4)	0	11.1	10.0
Highest Level of Education, %			
Some College (n=50)	84.2	94.4	85.0
Bachelor's Degree (n=6)	15.8	5.6	10.0
Master's Degree or Higher (n=1)	0	0	5.0
Height, mean cm	169.0 \pm 10.1	165.8 \pm 6.1	171.3 \pm 9.8
Weight, mean kg	71.5 \pm 14.5	67.4 \pm 10.9	72.6 \pm 15.3
BMI, mean (kg/m ²)	24.9 \pm 3.5	24.4 \pm 3.3	24.6 \pm 3.8

Abbreviated terms: BMI – body mass index, cm- centimeters, kg – kilograms, MVPA – moderate to vigorous activity, N – number of participants in group, and sd – standard deviation.

Appendix D: List of Figures

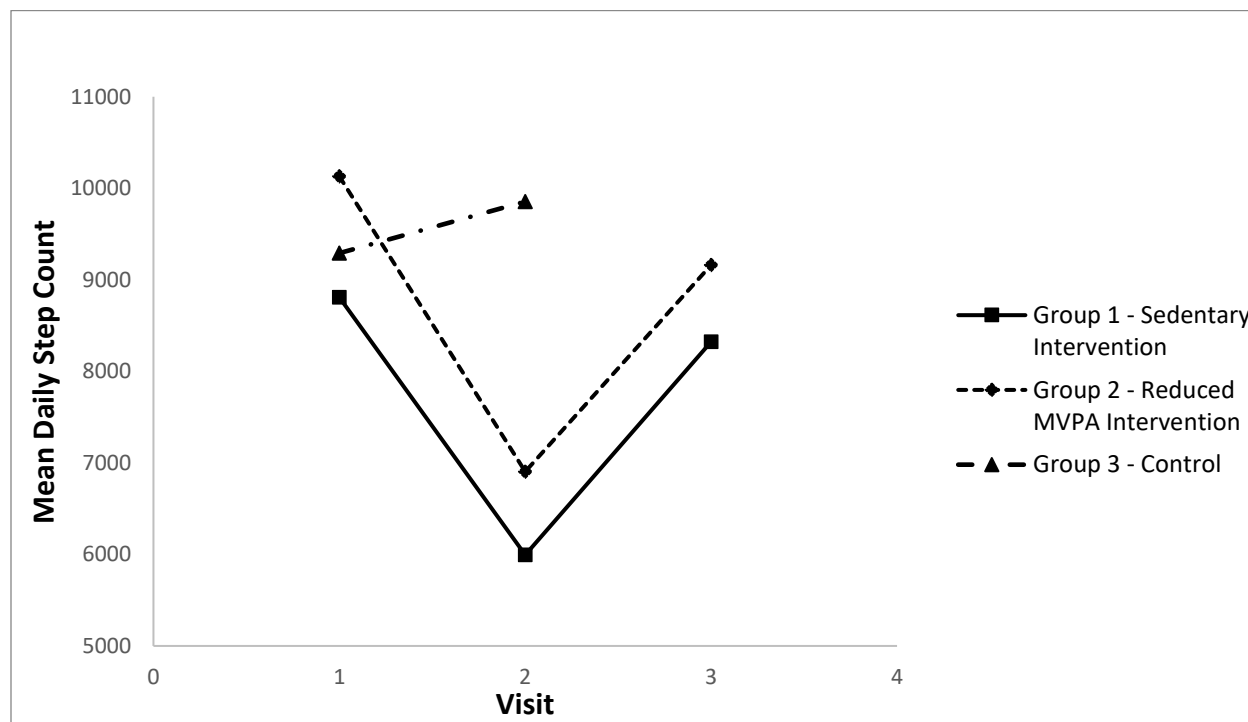


Figure 1. Mean changes in daily accelerometer-derived steps across the 3 time points for the 3 groups (Sedentary Intervention Group, Reduced MVPA Intervention Group and Control Group).

The 2 (group) x 3 (time) RM-ANOVA results were as follows:

$F_{\text{Time}} = 35.72, P < 0.001, \eta^2_p = 0.56.$

$F_{\text{Interaction}} = 0.24, P = 0.78, \eta^2_p = 0.009.$

The 3 (group) x 2 (time) RM-ANOVA results were as follows:

$F_{\text{Time}} = 33.86, P < 0.001, \eta^2_p = 0.40.$

$F_{\text{Interaction}} = 16.05, P < 0.001, \eta^2_p = 0.39.$

For the Sedentary Intervention Group, the mean (SD) daily step count estimates across the 3 respective time points were: 8808.2 (2157.0), 5994.8 (2148.6), and 8323.0 (2287.7).

For the Reduced MVPA Intervention Group, the mean (SD) daily step count estimates across the 3 respective time points were: 10129.7 (2383.8), 6904.5 (2246.6), and 9160.8 (2938.5).

For the Control Group, the mean (SD) daily step count estimates across the 2 respective time points were: 9286.7 (3105.0) and 9854.1 (2855.9).

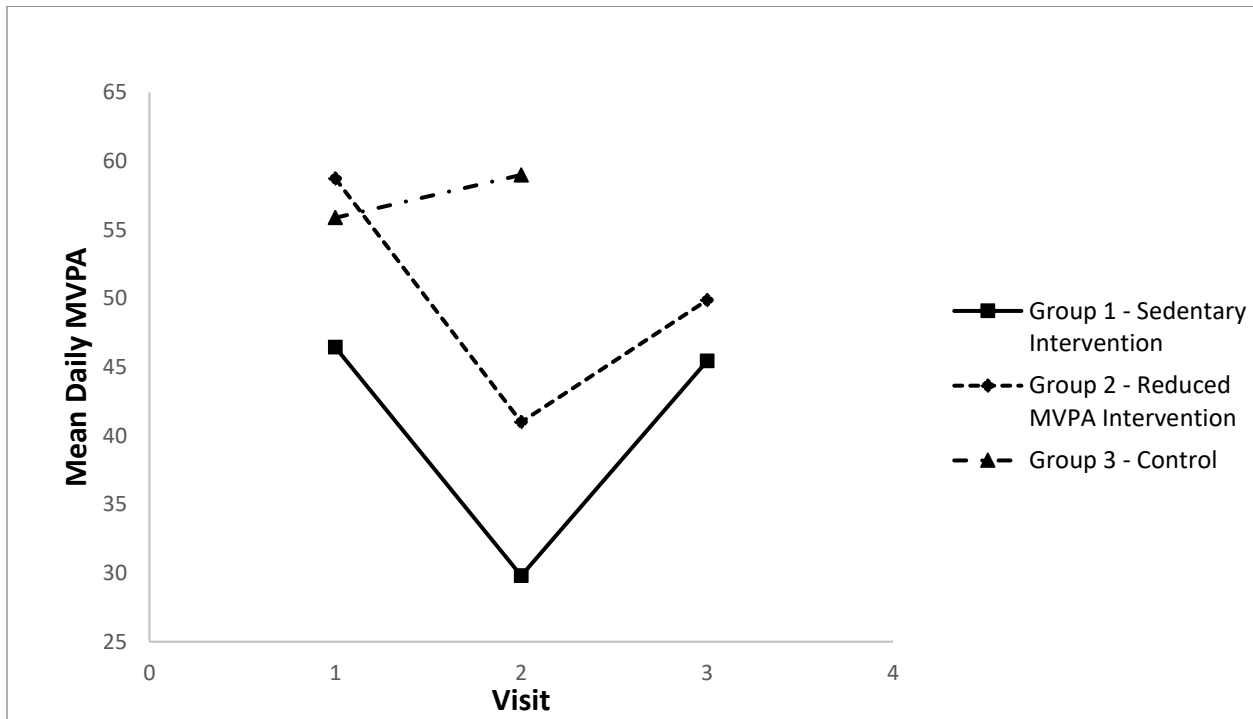


Figure 2. Mean changes in daily accelerometer-derived MVPA (moderate to vigorous physical activity) across the 3 time points for the 3 groups (Sedimentary Intervention Group, Reduced MVPA Intervention Group and Control Group).

The 2 (group) x 3 (time) RM-ANOVA results were as follows:

$F_{\text{Time}} = 17.01, P < 0.001, \eta^2_p = 0.38.$

$F_{\text{Interaction}} = 0.98, P = 0.381, \eta^2_p = 0.03.$

The 3 (group) x 2 (time) RM-ANOVA results were as follows:

$F_{\text{Time}} = 11.55, P = 0.001, \eta^2_p = 0.19.$

$F_{\text{Interaction}} = 5.31, P = 0.008, \eta^2_p = 0.18.$

For the Sedimentary Intervention Group, the mean (SD) minutes per day in MVPA across the 3 respective time points were: 46.4 (17.8), 29.8 (14.7), and 45.4 (18.6).

For the Reduced MVPA Intervention Group, the mean (SD) minutes per day in MVPA across the 3 respective time points were: 58.7 (18.8), 41.0 (20.5), and 49.9 (23.5).

For the Control Group, the mean (SD) minutes per day in MVPA across the 2 respective time points were: 55.9 (28.1) and 59.0 (29.8).

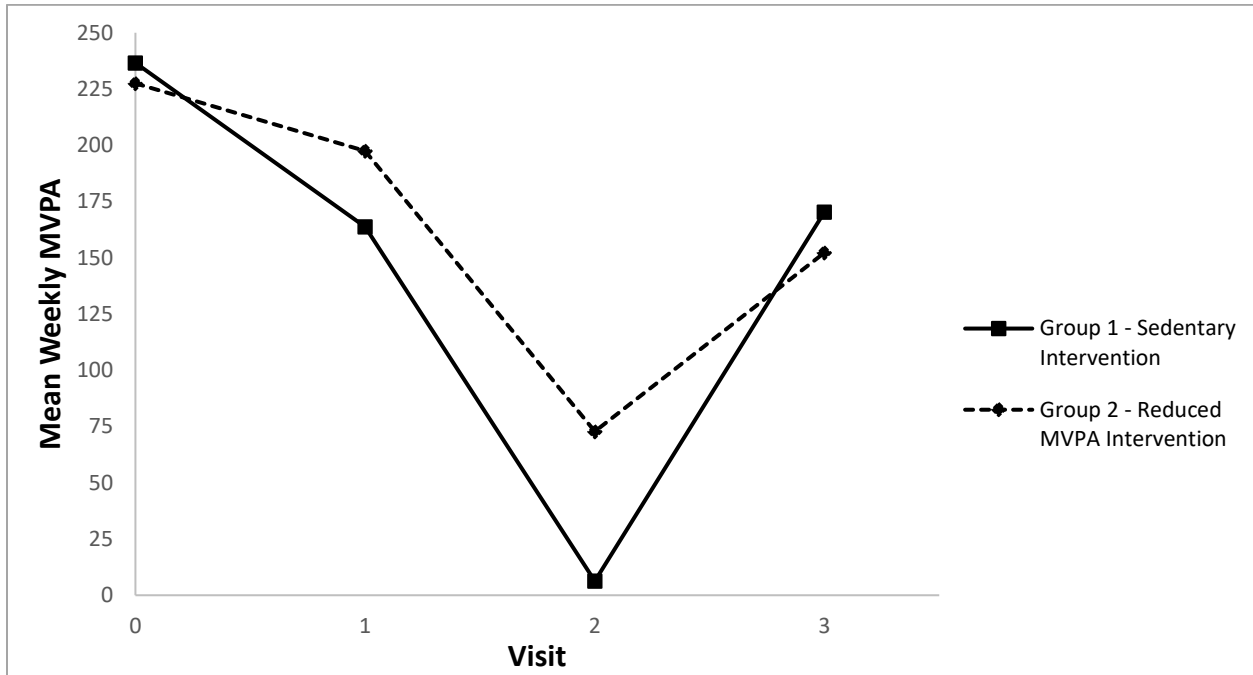


Figure 3. Mean changes in weekly MVPA (moderate to vigorous physical activity) via the PAVS assessment across the 4 (Visit 0 being the initial baseline assessment) time points for the 2 intervention groups (Sedentary Intervention Group and Reduced MVPA Intervention Group).

The 2 (group) x 4 (time) RM-ANOVA results were as follows:

$F_{\text{Time}} = 58.06, P < 0.001, \eta^2_p = 0.63.$

$F_{\text{Interaction}} = 3.41, P = 0.02, \eta^2_p = 0.09.$

For the Sedentary Intervention Group, the mean (SD) minutes per week in MVPA across the 4 respective time points were: 236.6 (100.6), 163.7 (98.3), 6.3 (20.1), and 170.3 (91.9)

For the Reduced MVPA Intervention Group, the mean (SD) minutes per week in MVPA across the 3 respective time points were: 227.5 (71.2), 197.5 (67.5), 72.8 (51.8), and 152.2 (121.3).

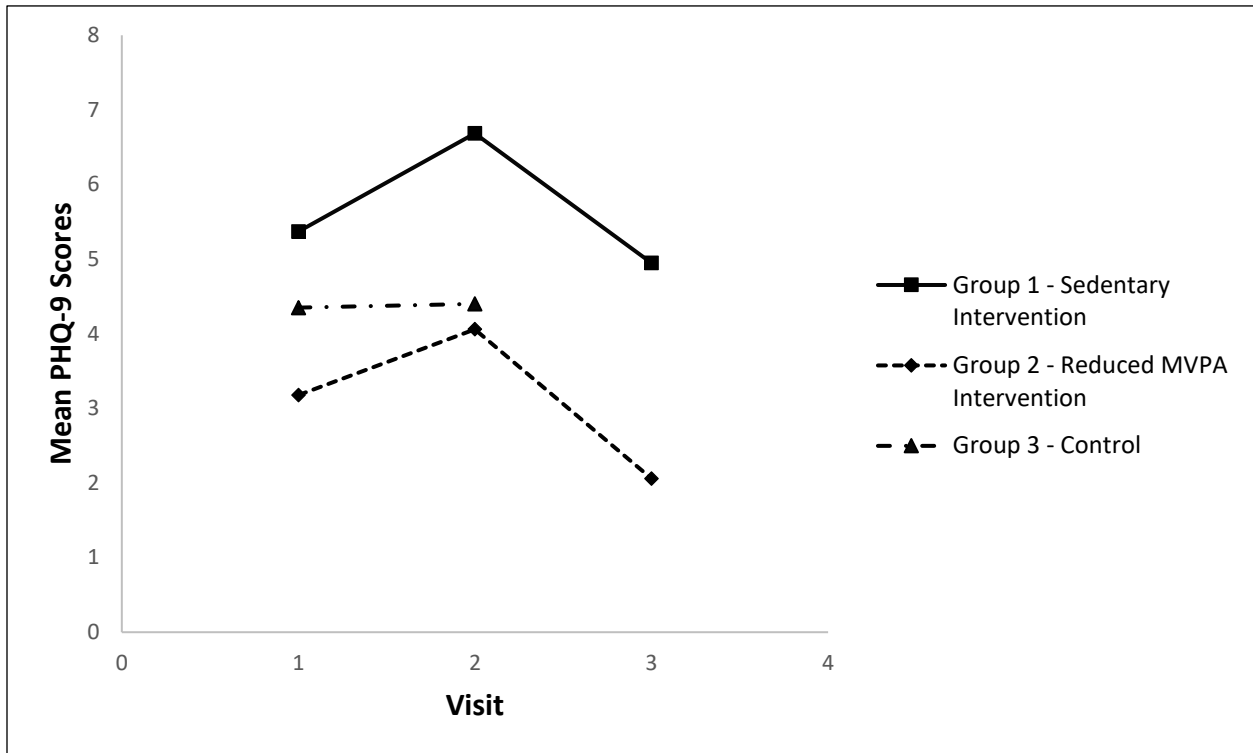


Figure 4. Mean changes in PHQ-9 across the 3 time points for the 3 groups (sedentary intervention group, reduced MVPA intervention group and control group).

The 2 (group) x 3 (time) RM-ANOVA results were as follows:

$F_{\text{Time}} = 7.86, P = 0.001, \eta^2_p = 0.19.$

$F_{\text{Interaction}} = 0.28, P = 0.76, \eta^2_p = 0.01.$

The 3 (group) x 2 (time) RM-ANOVA results were as follows:

$F_{\text{Time}} = 6.07, P = 0.01, \eta^2_p = 0.10.$

$F_{\text{Interaction}} = 1.49, P = 0.23, \eta^2_p = 0.05.$

For the Sedentary Intervention Group, the mean (SD) PHQ-9 estimates across the 3 respective time points were: 5.4 (5.3), 6.7 (5.0), and 4.9 (4.6).

For the Reduced MVPA Intervention Group, the mean (SD) PHQ-9 estimates across the 3 respective time points were: 3.2 (2.7), 4.1 (3.4), and 2.1 (1.9).

For the Control Group, the mean (SD) PHQ-9 estimates across the 2 respective time points were: 4.4 (3.4) and 4.4 (3.7).

VITA

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