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Research Article

Physical Activity and the Prevention of Depression: A Longitudinal Analysis of a South African Database

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ABSTRACT

Background: Growing evidence suggests physical activity is a modifiable protective factor that may reduce risk of developing depression. However, research has predominantly come from high income settings, is often cross-sectional, may not address differences in levels of physical activity, and has not emphasized potential sex differences. Discovery is the largest private medical insurance provider in South Africa and its Health and Vitality database provides a unique resource for addressing these gaps.

Methods: This retrospective cohort study consisted of deidentified health and physical activity data containing 49,397 unique individuals from the period 2013-2015. Participants were categorized by change in physical activity level after 3 years and depression incidence was compared among these cohorts. Propensity scores were used to account for physical activity cohort selection factors. The analysis also tested for sex by cohort interaction and conducted stratified analyses by sex.

Findings: Females had almost double the incidence of depression as compared with males in the sample period. Post hoc tests for the interaction indicated that increased physical activity reduced risk of depression for females ($F2, 49397=9.18$, $p<0.0001$) but no significant affect was noted for males ($F2, 49397=0.19$, $p<0.83$). A small increase in physical activity showed a significant reduction of depression incidence in females.

Interpretations: The results extend previous findings on physical activity and depression to the South African population, finding increasing physical activity reduced depression for females. While the findings for males in the study were not statistically significant, prior research has shown that, for males, exercise may be an important preventative factor for depression.

Keywords: Physical activity; Depression; Exercise; Population

INTRODUCTION

More than 264 million people globally suffer from depression [1]. Additionally, depression has been significantly associated with comorbidities [2,3] premature mortality [4] and a financial cost to society [5]. The burden of depression is compounded by the gap between the need for and access to treatment, particularly in low- and middle-income countries, such as South Africa, where the lifetime prevalence of depression is 9.8% [2,6].

Observational studies demonstrate that physical activity is associated with reduced risk of onset of depression, while intervention studies indicated that physical activity reduces symptoms of depression [7-14]. Furthermore, analysis of the bidirectional relationship between physical activity and depression using data from Genome-Wide Association Studies (GWAS),

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indicates that physical activity has a causal protective relationship on depression [15,16].

Despite the growing evidence that physical activity prevents depression, there are at least four limitations of extant research. First, many studies are cross-sectional and, therefore, cannot evaluate the temporal relation between physical activity and depression. Such studies cannot differentiate whether physical inactivity increases the incidence of depression or whether depression causes reduced physical activity. While accumulating evidence suggests physical activity prevents the onset on depression [14,17-20], a reduction in physical activity as a consequence of depression is also well established [15,21] Second, studies have also not adequately addressed whether sex modifies the relation between physical activity and depression [17]. Sex differences such as the divergence in value of exercise types for males and females deserve more attention. Third, little is known about whether the type and extent of physical activity impact depression [19]. For example, Choi, et al. found that physical activity measured objectively (activity monitor) but not subjectively prevented onset of depression, 16 thus, future studies should use multiple indicators of physical activity. Finally, to date, most studies of the relation of physical activity and depression are from high-income countries [15]. It is unclear whether depression is a modifiable protective factor in low- and middle-income countries.

Discovery Health is South Africa's largest private medical insurance provider and Discovery Vitality is one of the largest health-promotion programmes in South Africa and globally. Discovery's Health and Vitality data base provides a unique opportunity to address these gaps in the literature. The database comprises tens of thousands of individuals in the South African population over many years, allowing us to investigate in a broad population from a low- and middle-income country context 1) The relationship between physical activity and the onset of depression, 2) Whether this relationship is modified by sex; and 3) Whether this relationship is modified by level of physical activity.

METHODOLOGY

This retrospective cohort study was undertaken comprising of data collected by Discovery Vitality and Discovery Health Medical Scheme of South Africa. Both companies form part of Discovery Limited a South African-founded financial services organisation that operates in the healthcare, life insurance, short-term insurance, savings and investments, banking, and wellness markets. Vitality's comprehensive lifestyle risk factor data is unique, given Vitality's broad reach over many years.

The dataset contained 949,747 unique de-identified individuals and the study cohort consisted of health and physical activity data containing 49,397 unique individuals from the period 2013-2015. This time period provided good data stability and consistency, as some measures were captured differently in earlier periods. All data was de-identified and all study participants provided written consent for the use of their data for research purposes through the Discovery programme. Ethics approval was granted by the University of Cape Town Human Research Ethics Committee.

Only individuals who had at least 3 years of continuous Discovery Vitality membership, from a starting year of 2013, and who have no known diagnosis of depression at baseline, were included in the study sample. As all members of the study population have private medical insurance, the study population may not be exactly representative of the South Africa's general population. 17.2% of South Africa's population has private medical insurance.

Data

The dataset includes both information derived from the medical insurance claim records as well as data related to participation in the Vitality programme as detailed in Table 1 in the appendix. Variables included depression diagnosis as per the International Classification of Diseases, Tenth Revision (ICD-10) flag, medical insurance plan type, age, sex, Socio-Economic Status (SES), Resource Utilisation Band (RUB) score (a score from 1-5 calculated on the value of overall medical insurance claims an individual makes in a year, 5 being the highest) and physical activity points.

SES is scored from 0 to 10, with 10 being the highest SES and 1 being the lowest. This measure is a proxy measure based on postcode (area code) and is not a score based on individual level income. Medical insurance plan types include active and dormant plans, although no dormant plans were noted in the data. These plan types offer a varying range of medical insurance cover and may offer varying benefits. For the time period studied, only the 'Executive' and 'Comprehensive' plans covered depression as part of their medical insurance benefits. However, Discovery Health does allow member medical savings accounts across plans, which could cover medical costs including those incurred from depression.

Physical activity points ranged from 50 to 300 points per physical activity event recorded, [22] as determined by the type and duration of physical activity event engaged (see Table 1). In order to isolate and assess the effect of physical activity on the prevention of depression, a change in physical activity over a three-year period (2013-2015) was the exposure variable. All individuals started in the 'low' physical activity group at year 1 and either remained in the 'low' group at year 3 or moved to the 'moderate' or 'high' groups. The physical activity variable, physical activity points, was categorized into quartiles to represent low (quartile 1,>0-25%), moderate (quartile 2, 25-50%), and high (quartile 3 and 4, 50-100%), exercise groups. To stay in the low category, participants would have a maximum of 3150 points for the year, this translates to roughly 60 points per week, as outlined in Table 1.

For the analysis, depression incidence was compared at year 3 (2015). All individuals with 0 physical activity points were excluded from the study sample as the '0' category could include individuals who do not do any physical activity and individuals who complete physical activity, but do not record it. Only individuals with at least the first three consecutive years of data were included in the analysis as outlined in Table 2.

Statistical analysis

The analysis compared the proportion of respondents who were diagnosed with depression over a three-year period over three exercise cohorts. To correct for potential non-exercise related differences between the three cohorts; those who remained on low physical activity after 3 years, those who moved from low to moderate physical activity after 3 years and those who moved from low to high physical activity after 3 years; a propensity cluster matching approach was used [23]. To this end a univariate ordered logistic regression model was created which had the

Table 1: The physical activity variable, physical activity points.

Exercise category	Points per year	Point scoring activities
Low	>0 to 3,150 points ± 60 points per week or lower on average	50 points: 5,000–9,999 steps in a day 100 points: 10,000 steps in a day A gym visit: a swipe by access card into a Vitality recognized fitness facility A 30+ minute activity at 60%–69% of max heart rate, as measured by a connected smart device (smart devices including smartwatches, which are subsidized/ free through the Vitality programme)
Moderate	>3,150 to 7,800 ± 150 points per week or lower on average	A 30+ speed workout, as measured by a connected smart device (running at an average of 5.5+ km/hr or swimming at an average of 1.5+ km/hr or cycling at an average of 10+ km/hr).
High	>7,800 points Greater than ± 150 points per week on average	200 points: A 30+ minute activity at 70%–79% of max heart rate, as measured by a connected smart device. 300 points: A 60+ minute activity at 70%–79% of max heart rate, as measured by a connected smart device A 30+ minute activity at 80%–89% of max heart rate, as measured by a connected smart device Participating in a recognized 5km (or more) organised running events

Table 2: Study population.

		Depression
Starting population		949,747
Removed observations	84,272	Due to already being diagnosed with depression at or before year 1 (2013)
	91,338	Due to not having enough years of data (at least 3 continuous years)
	489,056	Due to not tracking any physical activity
	235,592	Due to not starting in the low physical activity category in year 1 (2013)
	92	Missing values in data
Final sample	49,397	

exercise group as the dependent variable and including physical activity points, age, sex, socioeconomic status, RUB score and medical insurance plan as independent variables. The predicted probabilities from the model were used to cluster the participants into groups of similar propensities. The clusters were checked to ensure that differences in member characteristics were not statistically significant. These clusters were then included in a generalized linear mixed model with the binary outcome of depression diagnosis at year 3 as the dependent variable, the exercise status in year 3 as the independent variable and the cluster group was included as a random variable to minimize potential selection bias due to difference in the groups.

The model assessed whether there was a main effect for exercise cohort, sex and the interaction between exercise cohort and sex and provided odds ratios and estimated probabilities of depression. Where significant differences were found, post hoc analyses, including Bonferroni adjustment for multiple tests, were performed to determine the nature of the differences.

RESULTS

Sample characteristics

Of the 49,397 records in the final study sample, 50.1% were female, 49.9% were male, with the average age being 40.8(± 11.1), as noted in Table 3. 5.8% of the study sample was diagnosed with depression during the study duration (i.e., the 2013-2015 period). The mean RUB score was 2.3 (± 1.2) and socioeconomic status was 6.4 (± 1.9). 23% of the sample belong to either the Comprehensive or Executive medical insurance plans.

The study sample and the excluded individuals were similar in characteristics with the exception of depression prevalence, with the study population having 5.8% depression prevalence and the excluded population having 11.7% depression prevalence. This was expected due to a prior or current diagnosis of depression at year 1 being an exclusion criterion for the study population Table 3.

Analysis

In the final model there was no significant difference for physical activity. However, there was a significant difference for sex ($F1, 49397=194.56$, $p<0.0001$), with a significant interaction between

sex and physical activity (F2, 49397=4.32, p=0.01). The sex effect showed the expected relationship with females having almost double the odds of depression.

Post hoc tests for the interaction indicated that there was a significant difference in the impact of exercise cohort for females (F2, 49397=9.18, p<0.0001) but not for males F2, 49397=0.19, p<0.83)[1] (Table 4). The odds ratios for physical activity cohort in the female group indicated that the low physical activity category had significantly higher incidences of depression than the moderate and high physical activity categories (T_{49397}=-3.74, p=0.0002 and T_{49397}=-3.09, p=0.002). respectively, but no difference was evident between the moderate and high physical activity categories (T_{49397}=-0.51, p=0.61)2 (Table 5 and Figure 1).

- As there are two comparisons the Bonferroni adjustment compared the p-value to α=0.025 rather than 0.05
- As there are three comparisons the Bonferroni adjustment compared the p-value to α=0.0133 rather than 0.05.

The analysis was also done using other physical activity variables categorized as low, moderate, and high categories including number of gym visits in a year, physical points earned from gym visits in a year and number of physical activity events recorded in a year and these all mirrored the findings of the physical activity points variable described above.

Table 3: Distribution of study sample.

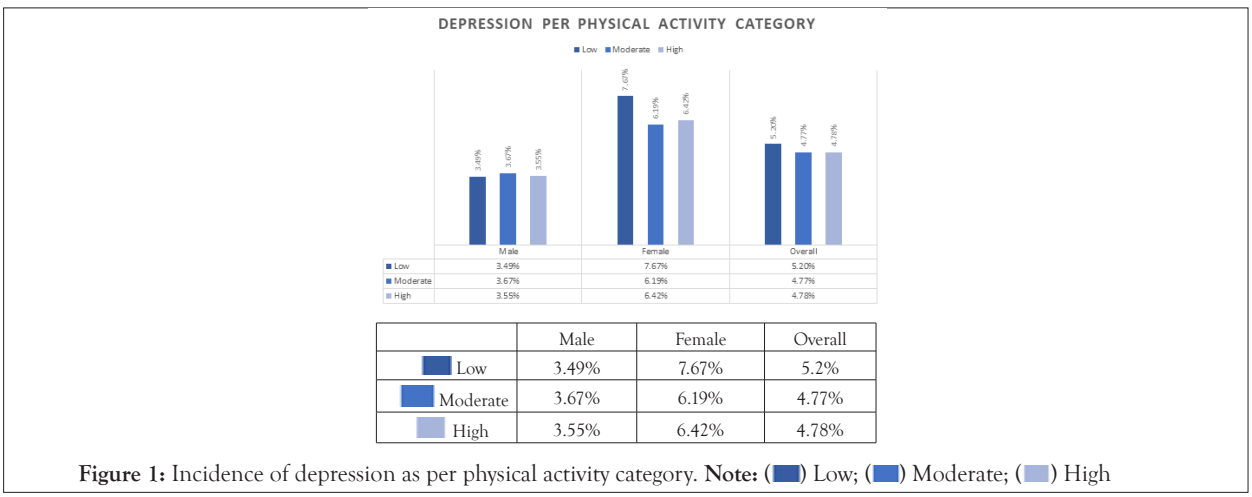
Variable	Category	Mean/Freq.	Median	SD	Min	Max	Excluded participants
Sex	Female	50.10%	-	-	-	-	51.50%
	Male	49.90%	-	-	-	-	48.50%
Age		40.8	40	11.1	18	93	44
Depression		5.80%	-	-	-	-	11.70%
RUB		2.3	3	1.2	0	5	2.4
Socio-economic status		6.4	6.5	1.9	1.2	9.8	6.1
Insurance plan type	Comprehensive	21.40%	-	-	-	-	21.80%
	Executive	1.60%	-	-	-	-	1.60%
	Smart	1.20%	-	-	-	-	1.10%
	Keycare	2.90%	-	-	-	-	4.20%
	Priority	12.00%	-	-	-	-	11.10%
	Core	17.60%	-	-	-	-	17.20%
	Saver	43.20%	-	-	-	-	42.90%
	Dormant	0.00%	-	-	-	-	0.00%
Physical activity points		6146.9	2250.0	10356.9	0	205 750.0	6 632.6

Table 4: Comparison of depression incidence by sex.

Comparison	Df	T value	Pr>|t|	Odds ratio
Male vs. female	49,397	-13.95	<.0001	0.51

Table 5: Comparison of depression incidence by physical activity for female participants.

Comparison	Df	T value	Pr>|t|	Odds ratio
Moderate *vs.* high	49,397	-0.51	0.609	0.96
Low *vs.* moderate	49,397	-3.74	0.0002	1.26
Low *vs.* high	49,397	-3.09	0.002	1.21



	Male	Female	Overall
Low	3.49%	7.67%	5.2%
Moderate	3.67%	6.19%	4.77%
High	3.55%	6.42%	4.78%

Figure 1: Incidence of depression as per physical activity category. **Note:** (■) Low; (■) Moderate; (■) High

DISCUSSION

The main findings were 1) A strong relationship between engaging in physical activity and reduced incidence of depression in females, 2) No effect of physical activity on depression for males; 3) A relatively small increase in physical activity, for example from increasing 50 physical activity points per week (e.g. 5000 steps one day in a week) to 100 physical activity points per week (e.g. one low intensity thirty minute physical activity in a week or one gym visit in a week), can significantly reduce depression incidence in females.

Our finding that physical activity is associated with depression prevention in females but not males is consistent with some previous work by Kim and colleagues [17] but contrasts with work in other regions that did not find a sex effect [14]. There are several possible explanations for the sex difference in our study. First, the diagnosis of depression in males is not made as often in males compared to females, thereby reducing power to detect an effect in males. In our study population 1761 females and 882 males were diagnosed with depression, representing a roughly 2:1 ratio. This aligns with prior studies that show that depression is twice as likely to be diagnosed in females compared to males [24,25]. There may be a few factors that result in males being diagnosed less with depression than females, including biological factors [26] as well as psychosocial factors that could affect the way males seek help for and experience depression [27,28]. Second, the preventative effect of physical activity may be found under different conditions in males, e.g. when moving from sedentary to physical activity for males which we were not able to analyse. Third, certain types of physical activity, which we were unable to differentiate here, may have differing effects on depression for males and females. Lastly, there may also be contextual factors in South Africa that make this a true effect in our population.

Our analysis indicated that increasing physical activity from low to moderate or from low to high in the female population could prevent 19.3% and 16.3% cases of depression, respectively. This finding is consistent with prior literature [10,13,14] from other regions. We extend these findings by demonstrating that a relatively small increase in exercise had a significant effect.

Several limitations deserve emphasis. First, the dataset does not include a number of variables that may moderate the relationship of physical activity with depression. These include medical history such as comorbidities that restrict physical activity, family history, individual socioeconomic status, and geographic location. With these variable and more detailed data on depression such as scale, we may have been better able to tease out the role that other risk factors play in the relationship between physical activity and depression. Second, we were also not able to include a completely sedentary or 'zero' physical activity categorisation, which may have biased our results to the null. That is, our reference group did not include persons who were completely sedentary and thus we were not able to demonstrate the effect of moving from a no exercise category to an exercise category. This may have led to our results being more conservative as it may have resulted in an underestimation of the effect size [29]. Third, an analysis using more specific data from activity trackers (linked smart watches and other devices measuring heart rate activity, duration, and type of physical activity) was not able to be used as the gradual take-up of these devices in the cohort resulted in a small available population and may have been biased to those who are more physically active. Finally, while the study population was a large South African cohort, it was a cohort with private medical insurance, which is not representative of the general population of South Africa. Private medical insurance is a paid for service and is therefore accessed by the population that can afford it. As a result, this population group is wealthier compared to the general population [30]. Nevertheless, key strengths of this study are the large cohort, the robust, long data collection, validated measures of physical activity and depression, and the credible demographic and confounder data that was available. All physical activity data was recorded either through devices, gymnasiums, or physical activity organised events (which contribute to physical activity points) and all diagnosis data came from a medical professional diagnosis, as is required by the medical insurance scheme.

CONCLUSION

In conclusion, this study indicates that physical activity is an important factor in the prevention of depression of females in a South African population. Future work in populations from other African and low to middle income countries is needed. In addition, assessment of specific types of physical activity would also add to this analysis. Our results suggest that health policies to ensure access and promotion of physical activity resources to prevent depression are key.

CONFLICT OF INTERESTS

Dr Motilal and Dr Mabunda are employed by Discovery Vitality (Pty) Limited. Dr Martin Stepanek is employed by Vitality UK. Dr Koenen, Dr Stein and Mr Greyling are consultants to Discovery Vitality (Pty) Limited. The data for the research is provided by Discovery Vitality (Pty) Limited and that entity may be affected by the research reported in the enclosed paper. All conflicts have been disclosed fully and authors have put in place an approved plan for managing any potential conflicts arising.

EVIDENCE BEFORE THIS STUDY

Growing evidence suggests physical activity is a modifiable factor that may reduce risk of developing depression. However, this research is based in high income countries, is often cross sectional and focuses more on the management of depression rather than on the prevention of the condition.

ADDED VALUE OF THIS STUDY

The detailed longitudinal dataset is a unique one and demonstrates the value of physical activity in preventing depression, especially for the female population in South Africa.

IMPLICATIONS OF ALL THE AVAILABLE EVIDENCE

As physical activity is potentially a low-cost prevention, it should be considered an important preventative tool for depression globally. Our research also suggests the need to further investigate potential mechanisms underlying the sex effect found, and to

develop health policies that take into account these findings.

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