Functional Ability Impacted By Combinations Of Physical Activity, Sleep Quality And Depression In An Aging Arthritis Population

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Abstract

Arthritis is a disorder that involves swelling and tenderness of joints. In arthritis, functional ability is impacted by the lifestyle factors physical activity (PA), sleep quality (SQ) and depression. In response to the COVID-19 pandemic limiting treatment options, this study aimed to find which binary combination of PA, SQ and depression most severely impacts functional ability in an aging arthritis population. Data from the 2011-2018 National Health and Nutrition Examination Survey was used (n=4969). Participants were grouped according to depression severity (DS) and further divided based on activity level and SQ. ANOVA evaluated differences in functional ability between active and inactive participants in each DS cohort before resegregating cohorts into subgroups of poor vs adequate SQ. The procedure was repeated, dividing participants into activity levels, and making subgroups based on SQ and DS. A multiple linear regression analysis assessed individual impact of PA, SQ and depression on functional ability. Inactivity impacted physical impairment in most DS groups, excluding the severe depression group ($p<0.0001$, $p<0.001$, $p<0.0001$, $p<0.0001$, $p< 0.9$). Poor SQ impacted physical impairment in the mild and no depression groups, and in groups with 0-9 occurrences of PA ($p<0.0001$ all). Mild to severe depression impacted physical impairment regardless of activity level ($p < 0.0001$). Depression explained more variance in functional ability than SQ and PA (Depression: $R^2 = 0.12$; Model overall: $R^2= 0.22$). The combination of inactivity and severe depression most severely impacted functional ability, supporting a holistic view of arthritis in treatments aimed at retaining functional ability.

Introduction

Arthritis is a disorder that involves swelling and tenderness of joints [1]. A recent report shows that 75% of people with Rheumatoid Arthritis feel unsatisfied with treatment outcomes [2]. An ineffective treatment disproportionately affects people in poorer or rural regions who cannot afford prolonged treatment or cannot sustainably attend physical therapy [3]. An obstacle in achieving remission might be unhealthy lifestyle practices. In patients with Rheumatoid Arthritis, recent studies suggest that smoking and BMI are predictors of early treatment outcomes. Conversely, depression due to stress and its physiological responses impact long-term

health outcomes [4-6]. Treatments focused on the physical aspects of arthritis do not account for the unhealthy lifestyle practices of patients, thus undermining positive treatment outcomes such as retaining functional ability.

In arthritis, retaining functional ability is essential to maintain workability, independence, and social interaction [1]. The ability to walk up a flight of stairs or pick up a utensil is crucial to one's feeling of control and agency over one's life. Unfortunately, limitations in functional ability are most common in an aging population [7]. According to several preliminary studies, lifestyle factors also play a role in the severity of functional limitations that interfere with quality of life [8-9].

Recently, the prevalence of lifestyle factors in managing arthritis symptoms has increased. The COVID-19 pandemic confined millions of Americans to their homes, unable to visit hospitals and clinics. The aging population has the highest risk of adverse health outcomes in response to COVID. As this population is more likely to be confined to their homes and exhibit a functional limitation, lifestyle practices could impact mobility and quality of life. Relevant lifestyle behaviors to investigate are physical activity (PA), mental health disorders, and non-restorative sleep [10-11]. In [12], patients that report a higher disease activity were found to exhibit increased depression and fatigue. By contrast, healthy lifestyle practices such as meeting national guidelines for PA can lower the risk of disability [9]. The altered lifestyle of someone confined to the home might also reduce physical and mental wellness. Unwanted changes to one's life and health could include not getting the same amount of daily exercise, a minimized level of social interaction, and an altered sleep schedule.

As these changes could impact functional ability, it is crucial to investigate how physical activity, depression, and non-restorative sleep affect functional ability.

In arthritis, physical limitations were associated with co-occurring depression and emotional distress [13-14]. Additionally, decreased functional capacity and poorer health function were linked to severe mental health disorders in adults with arthritis over 50 years of age [15-16]. Non-restorative sleep was also associated with higher levels of inflammation in older men resulting in a heightened risk of functional disability, with an increased risk of incident disability [17-18]. Such findings are concerning since arthritis patients have a lower sleep quality than the general population [19-20]. Lastly, inactivity and poor-related health status were associated with higher rates of disabilities, a lower degree of independence, and decreased

functional ability in adults over 75 years of age and [21-22]. Interventions to increase PA can lower the risk of physical disabilities [23].

The interrelations between inactivity, sleep, and depression are complex, yet they are critical to understanding how to improve the quality of life of arthritis patients. The relations between sleep and depression were found to be mediated by social interaction and result in increased levels of fatigue [24]. Other studies have looked at how exercise can be incorporated into mental health care to effectively treat mental illness [25]. Higher numbers of mentally unhealthy and physically inactive days were found to affect arthritis burden, lower levels of activity, and negatively impact mental health [26]. In [27], researchers found that increased exercise intensity reduced sleep disturbance and increased daytime dysfunction. However, this study was not conducted with an arthritis sample which leaves more to be clarified about the relation between physical activity and sleep in a population with arthritis. The overall schematics of the impacts that PA, sleep, depression have on functional ability are shown in Fig 1.

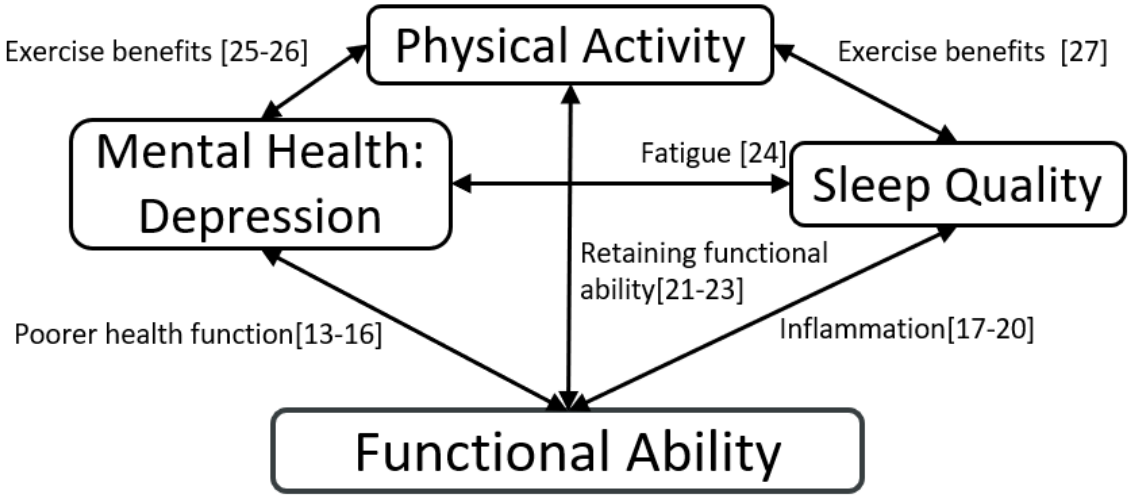

Fig 1. The direct connections between PA, sleep, and depression each have on functional ability. Also shows the interrelationships between PA, sleep, and depression that can have indirect effects on functional ability.

The individual effects of PA, sleep, and depression on functional impairment have been established, but research is lacking in how combinations of lifestyle factors can impact functional ability. Groupings of lifestyle factors should be researched more frequently to ensure findings are reflective of the holistic treatments being advocated for in literature. Therefore, this study aimed

to investigate which combinations of PA, sleep quality (SQ), and mild to severe depression are most impactful on functional ability. This study also aimed to find which individual lifestyle factor is most impactful on functional ability.

Methods

The National Health and Nutritional Examination Survey (NHANES) (https://www.cdc.gov/nchs/nhanes/index.htm) is a continuous program of the National Center for Health Statistics. Data is released in 2-year cycles and segregated by topic. The NHANES sample is representative of a national civilian, noninstitutionalized population aged 18 years and older. This survey is unique in its combination of interviews and physical examinations. Each participant visited the physician when answering questions on medical and dietary information. A national sample was obtained. Several counties were surveyed annually, indicating that multiple entries across data cycles could represent the same person.

Data Cleaning

All data was obtained from 4 survey cycles, 2011-2012 (n= 9756), 2013-2014 (n= 10175), 2015-2016 (n= 9971), 2017-2018 (n=9254) to increase sample size. RStudio was used for all data analysis. The R package *tidyverse* was used in mutating and obtaining subsets of data. The package *naniar* aided in excluding missing values from missing values in the cleaning process. The *Haven* package was utilized in reading data from .xpt files.

Variables:

Topics relevant to research objectives included Physical Functioning, Depression Screeners (excluding Youth Depression Screeners), Physical Activity, Sleep Disorders, Medical Conditions, and Demographic data. The topics Physical Functioning, Physical Activity, Sleep Disorders, and Depression Screeners are self-reported, which is a limitation of this study. Each variable is described below.

Physical Functioning

To measure physical impairment, a scale was created by summing up answers to nineteen prompts regarding difficulty completing daily tasks. NHANES variable names were PFQ061B-PFQ061T. Examples of prompts include “ By {yourself/himself/herself} and without

using any special equipment, how much difficulty {do you/does SP} have . . .walking from one room to another on the same level?" and "By {yourself/himself/herself} and without using any special equipment, how much difficulty {do you/does SP} have . . .using {your/his/her} fingers to grasp or handle small objects?". Each question ranged from 1 to 5, where 1 indicates "No difficulty", and a 5 indicates "Do not do this activity". When summing up responses, 1 was set equal to 0. As a result, scores measuring physical impairment ranged from 0 to 95, where it is not possible to score a 1.

Depression Severity

The PHQ-9 questionnaire was used in this study. The PHQ-9 established as a reliable and valid method of diagnosing depression and includes questions such as "Over the last 2 weeks, how often have you been bothered by the following problems: feeling down, depressed, or hopeless?" [28]. Each question was scored on a scale from "0" (not at all) to "3" (nearly every day). Scores to the PHQ-9 range from 0-27. NHANES variable names were DPQ010-DPQ090.

To assess depression severity (DS), the scale was divided into bins that were representative of mild (PHQ-9 > 4), moderate (PHQ-9 > 9), moderately severe (PHQ-9 > 14), and severe depression (PHQ-9 > 19) [28].

Physical Activity

In this study, PA was defined as participating in at least one occurrence of moderate travel, work, or recreational activities that cause small increases in breathing or heart rate for at least 10 minutes continuously. If participants did not engage moderate PA, they belong to the no PA group. Occurrences of moderate physical activity were observed in this study to get a more accurate look at PA over time [29]. Prompts to measure days of moderate activity included "In a typical week, on how many days {do you/does SP} do moderate-intensity sports, fitness or recreational activities?''. PA was calculated by combining responses to 3 prompts (NHANES variable names were PAQ625, PAQ670, PAQ640). The range was 0-21, where higher numbers indicate higher PA levels. This range represents occurrences of moderate physical activity in a typical week. All prompts about physical activity are from the Global Physical Activity Questionnaire (GPAQ). Validity of the GPAQ has been established previously [30-31].

PA was also divided into bins. The categories created were 0, 1-3, 4-6, 7-9,10-12,13-15,16-18,19-21 occurrences of PA. No PA refers to 0 occurrences of PA while engaging in PA refers to 1-21 occurrences of PA [29].

Sleep Disorders

The only prompt taken to measure sleep was the Yes or No question "{Have you/Has SP} ever told a doctor or other health professional that {you have/s/he has} trouble sleeping (TS)?". TS was chosen instead of sleep duration since fatigue and non-restorative sleep have been linked to reduced functional status, depressive symptoms, and lower sleep quality [32-33]. A "yes" to this question indicated poor SQ. Variable Name was SLQ050.

Demographics

The age and gender of participants were included and controlled for in the study to prevent possible confounders [34]. Other demographic data was not included in this study.

Arthritis

Arthritis was defined as responding 'Yes' to prompt "Has a doctor or other health professional ever told {you/SP} that {you/s/he} . . .had arthritis (ar-thry-tis)?" The NHANES variable name was MCQ106A. Data about lifestyle corresponded to participants that have arthritis based on the personal identifying number (NHANES variable name SEQN). Data was then filtered to exclude participants under 50. The final data frame included 4,964 participants with arthritis. Participant characteristics are shown in Table 1. This study did not control for the severity or duration of arthritis or differentiate between types of arthritis.

Table 1. Patient Characteristics for Arthritis group

		Arthritis Group (n= 4964)
Age		
	50-59	1174
	60-69	1750
	70-80	2040
Gender		
	Men	2010

Women	2954
Moderate Physical Activity (MPA)	
0 occurrences/ week	2127
1-3 occurrences/ week	968
4-6 occurrences/ week	845
7-9 occurrences/ week	629
10-12 occurrences/ week	228
13-15 occurrences/ week	129
16-18 occurrences/ week	32
19-21 occurrences/ week	6
Trouble Sleeping	
Yes	2130
No	2834
Depression Severity (DS)	
No Depression	3209
Mild Depression	919
Moderate Depression	371
Moderately Severe Depression	181
Severe Depression	75

**209 participants had missing data for depression scores, n= 4755

Statistical Analysis

Overview

Data was cleaned and filtered using the *Hmisc* and *Tidyverse* packages in R which are recommended for character string manipulation. *Hmisc* was also used to cut continuous scales into bins. Since the aim of this study was not to assess prevalence of a specific condition, sample weights were not used.

Exploratory Analysis

For this cross-sectional study, spearman's rank correlation was utilized to assess strength and significance of correlations between PA , DS, TS and physical impairment. For this analysis, DS and MPA were reverted to continuous variables. Age and gender were included in analysis to assess if age range or gender would be a strong confounder. The significance of correlations was found using the *Hmisc* package in R. The *corrplot* package was used to create the correlation matrix. This package is often used for data visualization.

Combinations Analysis

To find which binary combination of lifestyle factors is most impactful on physical impairment, the following procedure was utilized: The arthritis sample was divided into groups based on DS. Each DS group (e.g. mild depression, no depression) was broken up further depending on whether participants met the condition of having poor SQ. Then, statistical analysis would be done between people who have poor SQ vs adequate SQ in the same DS group. If significant differences were found, then that meant having poor SQ significantly increased chance of physical impairments in that DS group. This process was repeated for each DS group using ANOVA. After, the condition would be changed so each DS group would be broken up based on whether participants exhibited PA or no PA. The variable (e.g. SQ or PA) that causes largest number significant differences across DS groups will be deemed most impactful.

The procedure was repeated, and the arthritis sample was divided into PA groups to observe whether the combination of PA and TS, or PA and having depression most severely raised the level of physical impairment.

Analyses involving depression had a slightly smaller sample size due to exclusion of participants with missing data (n=4755). The categorical versions of the DS and PA variables were used in this analysis to allow for analysis between behavior and lifestyle factors. The

ggpubr R package was used to create boxplots observed below. This package is often used for data visualization.

Physical Activity vs Sleep Quality

The combination of poor SQ and depression was compared with the combination between no PA and depression regarding impact on functional ability. This approach was used to find which combination is most impactful on physical impairment. First, each DS group (e.g. mild depression, no depression) was broken up further depending on whether participants met the condition of having poor SQ. Then, statistical analyses were done between people who have poor SQ vs adequate SQ in the same DS group. Finding significant differences between poor SQ vs adequate SQ would indicate that poor SQ is associated with a more severe level of physical impairment in that DS group.

This process was repeated for each DS group using ANOVA. After, the condition was changed so each DS group was broken up based on whether participants exhibited PA or no PA. The same process of finding significant differences across each DS group would follow to see if no PA significantly impacted physical impairment. The variable (e.g. SQ or PA) that caused the largest number significant differences across DS groups was deemed most impactful in combination with depression.

Sleep Quality vs Depression Severity

The combination of poor SQ and no PA was compared with the combination between having depression and no PA. This approach was used to find which combination is most impactful on physical impairment. Participants in the arthritis group were divided based on the number of occurrences of PA in a typical week (e.g. 0, 1-3, 4-6,7-9,10-12,13-15,16-18,19-21 occurrences of PA). Participants in the PA groups were further divided based on whether they met the condition of having poor SQ. ANOVA was used within each activity group to determine if significant differences exist between groups with poor SQ vs adequate SQ. Finding significant differences between poor SQ vs adequate SQ would indicate that poor SQ is associated with a more severe level of physical impairment in that PA group.

The condition would later be changed to compare depression vs not having depression. This meant that within each activity group, participants would be further divided if they had depression vs if they do not have depression. A PHQ-9 score of 4 or lower indicates no depression. ANOVA was used to determine if significant differences exist between the

depression and no depression groups. This step was repeated for each activity group. The condition (e.g. having depression or poor SQ) that resulted in the highest number of significant differences across activity groups was deemed most impactful in combination with no PA.

Individual Factors:

To find how much variance in physical impairment scores can be explained by SQ, DS and MPA individually, a multiple linear regression model was run. The *car* package in R was utilized to execute the regression model. Age and gender controlled for in this model.

Results

The goal of this study was to assess which binary combination of PA, SQ and depression was most impactful on physical impairment. The sample population in this study included adults with arthritis over fifty years of age.

Exploratory Analysis

Physical impairment was found to have moderate to weak relationships with DS ($r = 0.35$), occurrences of PA ($r = -0.24$), Age ($r = -0.14$), and SQ ($r = -0.19$). No collinearity was found in the sample, although DS had a moderate negative correlation with TS ($r = -.029$), PA ($r = -0.9$), and Age ($r = -0.15$). Age also had correlation with PA ($r = -0.14$) and SQ ($r = 0.13$). All correlations had a significance threshold of $p < 0.01$. Results shown in Fig 2.

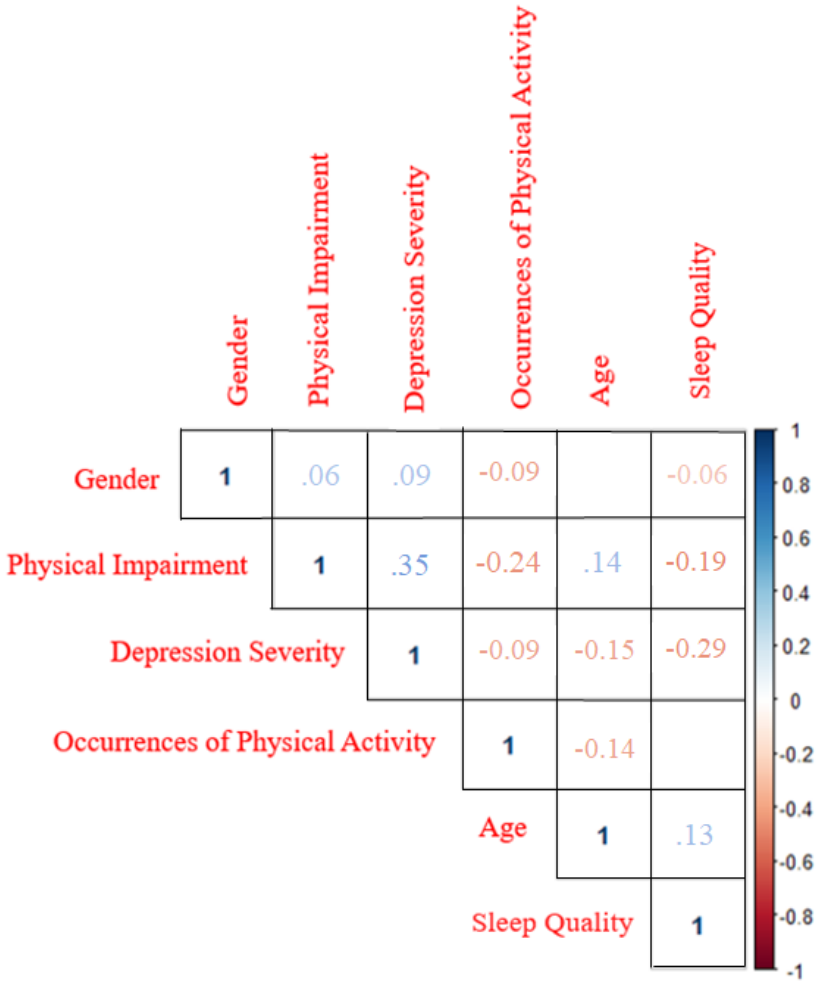

Fig 2. Correlation matrix between independent variables, possible confounding variables and physical impairment. Made using Spearman's Rank correlation, $p < 0.01$ for all shown

Physical Activity vs Sleep Quality

To assess if physical impairment was more impacted by the combination of no PA and depression or poor SQ and depression, ANOVA tests were run. To assess SQ's impact on physical impairment, significant differences were found between groups that had poor SQ vs. adequate SQ within each DS group. Significant differences between physical impairment scores were found only in the mild ($p<0.01$) and no depression ($p< 0.0001$) groups (Fig 3). By comparison, in the moderately severe, moderate, mild and no depression groups, significant

differences were found between the no PA vs PA groups regarding physical impairment scores ($p<0.0001$, $p<0.001$, $p<0.0001$, $p<0.0001$). No such differences were found between participants that were active vs. inactive in the severe depression group ($p<0.9$);(Fig 4). SQ and depression individually each had a significant impact on physical impairment ($p<0.0001$ all); no interactions between independent variables were significant.

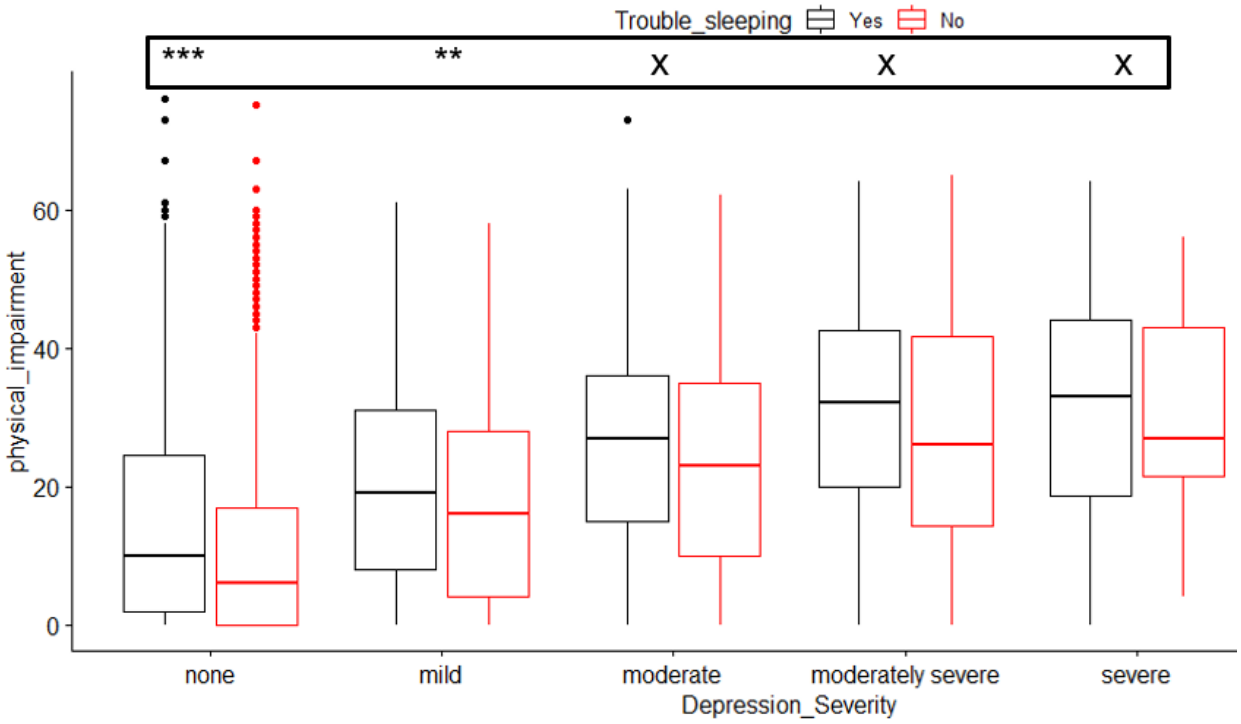

Fig 3. Distribution of physical impairment scores across depression severities. Subgroups divided based on whether participants had trouble sleeping in the past week; ($p < 0.0001$ = ***; $p< 0.001$= **; insignificant = " x")

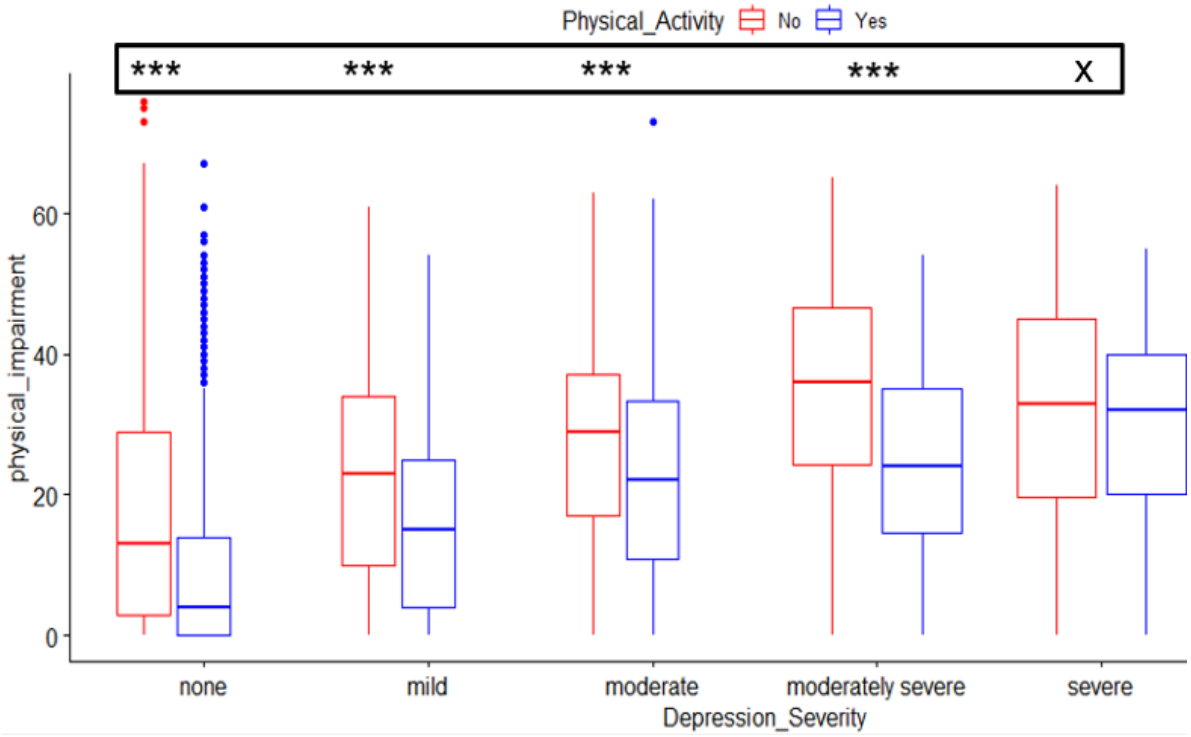

Fig 4. Distribution of physical impairment scores across depression severities. Subgroups divided on whether participants had at least one occurrences of moderate PA; ($p < 0.0001$ = ***; $p < 0.001$= **; insignificant = " x")

Sleep Quality vs Depression Severity

To assess if physical impairment was more impacted by the combination of poor SQ and PA or having depression and PA, ANOVA tests were run . The poor SQ group had significantly higher physical impairment in groups that exhibited 0-15 occurrences of PA per week (Activity levels: 0, 1-3, 4-6, 7-9, 13-15);($p < 0.0001$, all). There were no significant differences in physical impairment between SQ groups in the bins of 10-12, 16-18 occurrences of PA($p<0.04$, $p< 0.2$); (Fig 5). The 19-21 occurrences of MPA group was excluded due to small sample size (< 30).

To assess depression's impact on physical impairment, significant differences were found between groups that had mild to severe depression vs. no depression within each activity group. By comparison, the mild to severe depression group significantly impacted physical impairment scores in all PA groups (0, 1-3, 4-6,7-9,10-12,13-15,16-18,19-21);($p < 0.0001$ all). The significance level of TS vs no TS is shown in Fig 6. The 19-21 activity level was excluded due to small sample size.

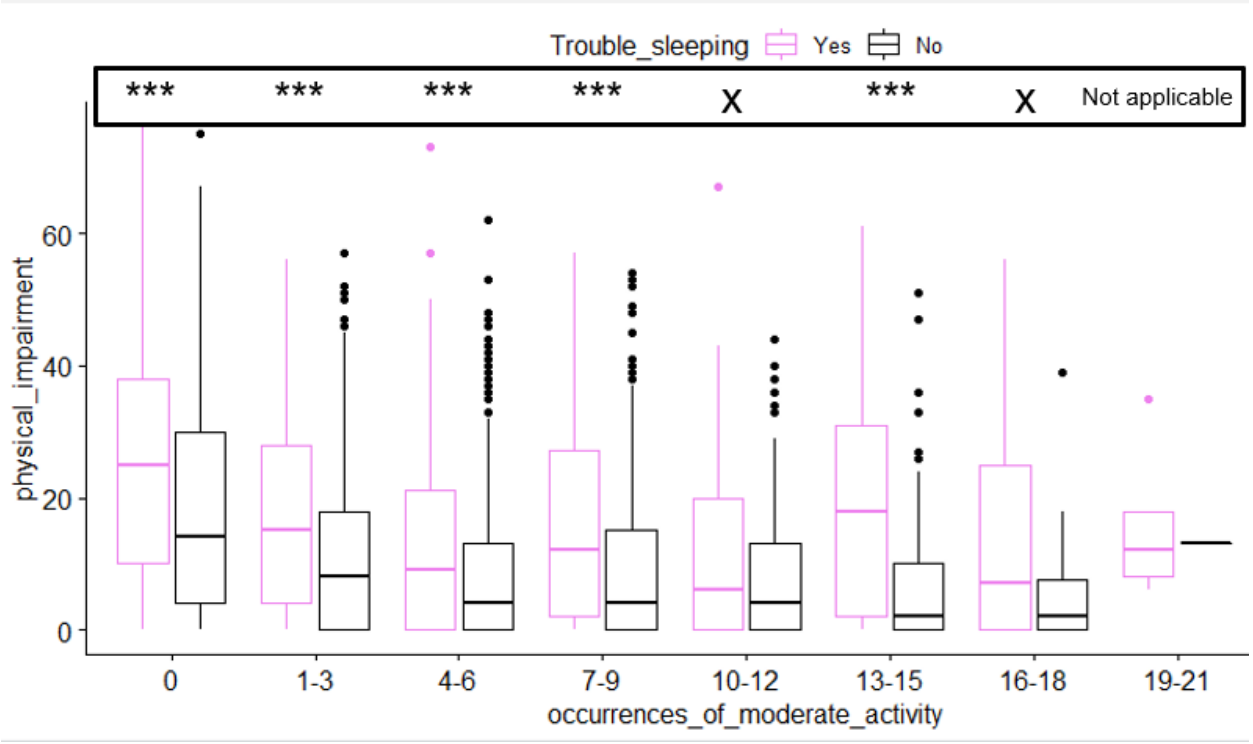

Fig 5. Distribution of physical impairment scores across occurrences of moderate PA. **Subgroups divided on** whether participants had trouble sleeping in the past week; ($p < 0.0001$ = ***; $p < 0.001$= **; insignificant = "x ")

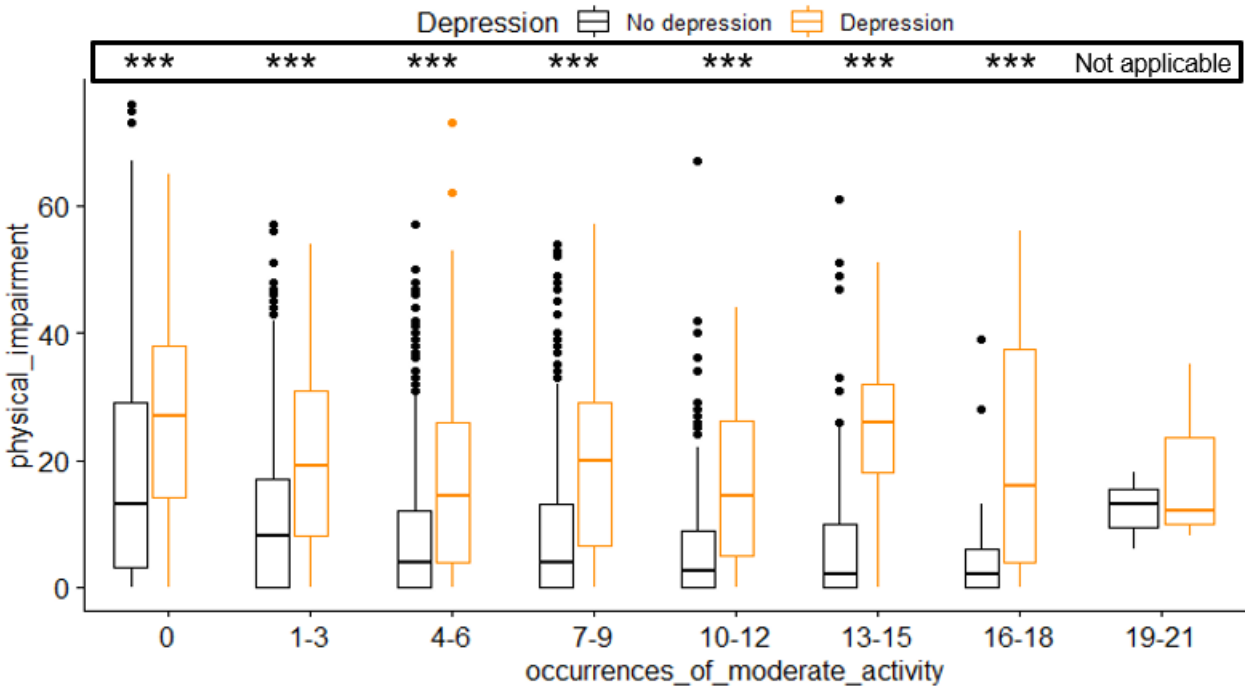

Fig 6. Distribution of physical impairment scores across occurrences of moderate PA. Subgroups divided on whether participants had depression; ($p < 0.0001$ = ***; $p < 0.001$= **; insignificant = " x")

Individual Lifestyle Factors

Multiple linear regression was used to identify how much variance in physical impairment scores is individually attributed to PA, SQ and mild to severe depression within the sample. In the final model, gender and age were controlled for. PA, TS and depression explained 22% of the variance in physical impairment scores. Depression explained 12% the variance , followed by PA (6%) and TS (4%).

Discussion

This study aimed to find which combinations of the lifestyle factors PA, SQ and depression have the greatest impact on functional ability in individuals with arthritis over fifty. To accomplish this study's research goals, the scientists first determined the combined effects of inactivity and depression on functional ability and compared it to the effects of exhibiting poor SQ with depression. Across all depression severities, excluding the severe depression group,

there was a highly significant difference in level of physical impairment between inactive and active people with arthritis over 50 years of age. This significance suggests that PA is associated with lower levels of physical impairment in people with arthritis who also have none to moderately severe depression. This finding supports efforts to increase PA in arthritis patients by as little as 1 day a week. This finding is similar to [29] where researchers found that significant differences among mental wellbeing in participants that were inactive vs those that participated in exercise at least 1 day per week. The positive impact that exercise had on functional ability, even among people with depression was also observed in [35]. This study incorporated exercise into mental health care for people with arthritis and mental illness and observed a decrease in functional limitations. Taken together, these findings suggest that PA may directly impact physical impairment, and indirectly impact physical impairment through depression [36]. The association between depression and PA in impacting physical impairment might be applied to other mental health issues. The role of anxiety in limiting functional ability should be further researched to avoid grouping together mental illnesses that have different responses to similar biological treatments [37].

By comparison, physical impairment was only significantly impacted by SQ in groups with mild and no depression. This suggests that measures to improve SQ might not be as beneficial as efforts to increase PA. Since increasing frequency of PA is an affordable lifestyle change, it should be further emphasized as part of treatment options and regarded as a treatment confounder in people with arthritis and milder forms of depression over fifty. Improving SQ is also an affordable lifestyle change, although it might only be beneficial in people with mild and no depression. Further research should be done to identify how different doses of sleep can impact functional ability in an older arthritis population [38].

Additionally, this study determined the combined effects of poor SQ and PA on physical impairment scores and compared it to the effects of depression and PA. Within most activity levels, physical impairment was higher in the poor SQ groups than the group with adequate SQ. There were two exceptions(10-12, 16-18 PA groups). This suggests that poor SQ impacts physical ability in inactive individuals and individuals with fewer occurrences of moderate physical activity. Interestingly, depression had a consistent significant impact on physical impairment. The combination of no PA with depression was seen to be more impactful on physical impairment than any other combination. It is plausible that higher physical impairment

was observed in groups that were inactive because of the positive benefits associated with tolerable exercise including improving FA [39-40]. However, the significant difference in PA across depression severities was observed in all depression groups except severe depression. That might indicate that in cases of severe depression in arthritis, more aggressive treatment is needed to improve mental health [41].

It is unclear if the findings of the Inactivity/Depression combination having the strongest association with physical impairment is due to the indirect effects stemming from the relation between PA and depression. The degree to which a bidirectional relation between PA and depression impacted these results remains unclear because causality could not be established in this study. Future research should compare the degree to which indirect effects can impact functional ability when depression is known to be impacting PA [42-43]. The Spearman's rank correlation did find that Depression (0.35), and PA(-0.24) had the strongest correlation to physical impairment, further supporting the findings of the multiple linear regression. However, the spearman's rank correlation found that DS and TS had a moderately strong relation with each other (-0.29) while DS and occurrences of PA had a weak correlation (-0.09). This suggests that interrelations between lifestyle factors are not always indicative of lifestyle factors having strong associations with functional ability.

It is important to note that the sample size of adults over fifty might have impacted findings. Results from the correlation matrix suggest that age can directly affect functional ability. Age can also have an indirect effect on functional ability through its correlation with PA, SQ and depression. In [44], researchers saw that the presence of an age-related health issue raised the likelihood of multimorbidity being associated with functional limitations in men over 50 years of age. This suggests that age can impact functional ability through several lifestyle factors. Further investigation is needed into mediating effects of age regarding functional ability. Because it is common for older adults to experience comorbidities in both medical and psychiatric fields, examining a younger sample might change distributions regarding PA levels or functional impairment [45]. Treatment outcomes in younger populations of arthritis should be studied separately because of the devastating long term impact arthritis can have on mental health, work ability, medical costs and economic losses [34, 41, 46].

Conclusions

These findings have provided insight into how functional ability is impacted by PA, SQ, and depression individually and in binary combinations. The inactivity and depression combination being most impactful on physical impairment suggests that adjunctive therapies to maintain stable mental health and increase PA should be incorporated into existing arthritis treatments [47-48]. Interventions to increase PA should also emphasize treatment adherence and take into account patient preferences to optimize treatment effectiveness [49-50]. The role of lifestyle factors in achieving remission needs to take into further account the vast array of lifestyles in the nationwide arthritis population. The COVID-19 pandemic has changed lifestyle practices worldwide. The negative implications of this event on functional ability should be investigated to better adjust treatments for patients.

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