Daily physical activity and depressive symptoms in adults: a systematic review

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Abstract

Depressive disorders pose a significant public health challenge, affecting over 300 million people worldwide (Gujral et al., 2017; WHO, n.d.). While it is known that physical activity can reduce depressive symptoms, the impact of daily physical activity on these symptoms remains unclear. This systematic review aims to enhance our understanding of how physical activity can reduce depressive symptoms in adults and to encourage future research and interventions in this field. The research question guiding this review is: 'What is the relationship between daily physical activity and depressive symptoms in adults?'. Irrelevant articles are excluded from the database, and the analysis is based on the remaining relevant studies. The findings reveal that the relationship between daily physical activity and depressive symptoms is complex and bidirectional. Individuals with depressive symptoms tend to be less active, which can worsen their symptoms, and reduced activity can, in turn, worsen depressive symptoms. The examination also considered the relation in terms of affect, because those experiencing depression typically show heightened negative affect (NA) coupled with a decline in positive affect (PA). Some studies found no significant association between NA and physical activity, regardless of individuals' depressive symptoms, while others demonstrated a significant effect of PA on physical activity. This review emphasizes the importance of further research into the specific mechanisms underlying this association to develop more effective interventions.

Key words: depressive symptoms, physical activity, adults, bidirectional relationship, positive affect, negative affect

Daily physical activity and depressive symptoms in adults: a systematic review

Depressive disorders pose a significant public health challenge, with an estimated prevalence of more than 300 million people worldwide according to the World Health Organization (WHO), (n.d.) and research by Gujral et al., (2017). Depression can negatively impact various areas of life, such as academic performance, workplace productivity, relationships with family and friends, community involvement (Mata et al., 2012; WHO, n.d.), and even the broader economy (Fostick et al., 2010; WHO, n.d). Therefore, it is crucial to investigate factors that can reduce or even prevent depressive symptoms.

In recent years, there has been a growing emphasis in scientific research on identifying factors that contribute to the development and progression of depressive symptoms. One promising area of investigation in this field is the impact of physical activity. Emerging evidence suggests a significant relation between physical activity and both the occurrence and severity of depressive symptoms in adults (Dishman et al., 2006; Schuch et al., 2016). Studies indicate that engaging in physical exercise may reduce mild to moderate forms of depression (Hallam et al., 2022; Harvey et al., 2018; Rebar et al., 2015). In fact, physical activity may be comparably effective to antidepressant medication in reducing mild to moderate depressive symptoms (Gujral et al., 2017; Hallam et al., 2022; Van Gool et al., 2003). Individuals experiencing depressive symptoms may engage in less physical activity due to the impact of these symptoms (Codella & Chirico, 2023; Rosmalen et al., 2012). Individuals experiencing depressive symptoms may engage in less physical activity due to the impact of these symptoms (Codella & Chirico, 2023; Rosmalen et al., 2012). The connection is influenced by various moderating factors, such as age, gender, activity intensity, and the severity of depressive symptoms (Schuch et al., 2016). Consequently, the relationship between depressive symptoms and physical exercise appears to be

complex and potentially bidirectional.

To gain a better understanding of this relationship, research has examined the neurobiological aspects of exercise in relation to depression. This provides a deeper understanding of the mechanisms underlying the association. Exercise produces its antidepressant effects through several physiological and psychological pathways. Physiologically, exercise increases levels of endorphins and other neurochemicals that improve mood (Dishman et al, 2006). In addition, studies have investigated the overlap between structural brain abnormalities in depression and the effects of exercise on brain structure. A notable feature of depression is a reduction in hippocampal volume (Bremner et al, 2000; Gujral et al, 2017). There is evidence that exercise can, among other things, increase hippocampal volume (Dishman et al., 2006; Gujral et al., 2017). This suggests that physical activity may help to moderate some of the changes in brain structure associated with depression.

Individuals experiencing depression typically exhibit increased negative affect (NA) alongside a decrease in positive affect (PA), which are typical signs of depression (Bos et al., 2018; Wichers et al., 2012). Consequently, PA and NA are frequently examined in studies investigating the relation between physical activity and depressive symptoms (Bos et al., 2018; Mata et al., 2012; Wichers et al., 2012). While much attention is given to NA in depressed individuals, PA is also of great interest in this context showing that it positively influences mental health, including modifying depressive symptoms (Bos et al., 2018; Mata et al., 2012).

While numerous studies have explored the relation between physical activity and depression, the results often vary concerning moderating factors, significance, and the direction of the relationship, leading to uncertainty about its exact nature. Some studies have found strong correlations between physical activity and depression (Codella & Chirico, 2023; Dishman et al.,

2006; Schuch et al., 2016), while others have yielded inconclusive findings (Harvey et al., 2018). These discrepancies may arise from differences in research design, characteristics of the studied populations and the methods used to measure physical activity and depressive symptoms (Rebar et al., 2015).

Given the complexity of the relationship and the inconsistencies in the literature, a systematic review is required. While much of the existing research has examined physical activity cross-sectionally, this review focuses on daily measured physical activity. Measuring physical activity on a daily basis provides a more accurate understanding of its relationship with depressive symptoms. This approach avoids the limitations of single point measurements and aims to provide a more reliable and comprehensive outcome. Research comparing daily measurements with more intermittent measurements suggests that daily measurements provide more accurate results and may increase statistical power (Nebe et al., 2023). The aim of this systematic review is to provide a thorough overview of the existing evidence on the relationship between daily physical activity and depressive symptoms in adults, focusing on the direction of the association and the strength of the evidence. The research question of this review is: 'What is the relationship between daily physical activity and depressive symptoms in adults? By providing an in-depth understanding of this relationship, this review aims to improve our knowledge of how physical activity can promote mental health in adults and to inform future research and interventions in this area.

Method

Protocol and Registration

The study was designed and written following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)

guidelines (Page et al., 2021). To ensure a transparent and reproducible research process, the review method, search strategy, screening procedure, and plans for data extraction were specified and documented in a protocol a priori, which is registered with OSF and accessible via https://osf.io/24auc.

Search Strategy and Information Sources

The literature was conducted in Web of Science searching Core Collection and MEDLINE databases, and PsychINFO through EBSCOhost. Moreover, the process of searching for the included articles revolved around three main components. The first component represents the stress concept, the second component consists of the mental health outcome, and the third component consists of studies that include a daily measures design.

In order to search for these components, various query strings were used and combined using the "AND" prompt. For the stress concept, the strings included the following search terms: stress*, or "life event*", or "negative event*", or hassles, or trauma*, or abuse, or neglect, or "child* maltreatment", or "child* experiences", or violence, or disaster*. Meanwhile, for the mental health outcome, the following query strings were used: psychopathol*, or "mental disorder*", or anxiety*, or depress*, or "CIDI", or "DSM", or phobia*, or "ptsd", or "panic disorder*", or "GAD", or "MDD", or "MDE". Finally, for the daily measure design, the query strings that were used consisted of: diary, or daily, or "time series", or "time-series", or "experience sampling", or "ESM", or "ecological momentary assessment*", or "EMA", or "intensive longitudinal", or ambulatory, or "micro-longitudinal". These strings were searched in the abstract or title. Validation procedures were not used to conduct this literature search.

Eligibility Criteria

This review considered only empirical studies. Dissertations, reviews, comments, opinion

articles, books, book chapters, and others of similar nature were excluded. Protocols were included at the first stage to facilitate automatic prioritization in ASReview, but excluded during data extraction. Case studies (i.e. studies with a single participant) were also excluded. To be included in this review, articles had to use ambulatory measurements that were collected at least once a day for at least several consecutive days (i.e. ≥ 2 days in a row). These measures could include but were not limited to self-reported subjective measures, subjective measures reported by others, or objective measures (through a smartwatch or a similar device). If variables were measured daily but they only reflected a treatment that was administered daily (e.g. medication administration), or if the daily measurements came in the form of Intensive Care Diaries (ICD) taken by nurses on the general state of participants, the study was excluded. Finally, if daily measures were not measured in human participants but solely focused on global statistical reports (e.g. crime reports), the study was also excluded. This review only included human participants. During the full-text screening, articles were excluded if they were: not in English, if not empirical, if the full text was not available, or if the study had no daily measure.

Data Collection Process

Before the data collection, a pilot extraction was conducted in ASReview using automatic prioritization. The pilot extraction phase consisted of 15 sources. Based on the pilot screening sheet, the information to be extracted was adjusted. A data extraction sheet was developed in Google Spreadsheets where the characteristics of the selected studies were extracted and recorded. In the primary data extraction phase, twelve extractors were involved. The extractors had a training phase, after which they worked independently. During the extraction phase, extractors had the opportunity to ask their project leader questions formed as comments in the datasheet or during the weekly meetings. The process of data extraction was supervised by the

project leaders.

The following population characteristics from the included studies were extracted: country, sample size, age (mean or range), population type, population subtype, physical health (problem/diagnosis), and mental health (diagnosis). Furthermore, the following ambulatory variables were extracted: sampling frequency/day, type of report (self-report, objective measures, or both), stress, affect/emotions, cognition, physiology, behavior, coping, mental health concept and its measurement, and other variables measured daily. The extracted variables measured cross-sectionally were the exact same as the ambulatory variables, except for sampling frequency.

Study selection from the database

The database was searched for relevant studies for the research question of this thesis. Sources were searched in two ways. The first way was by selecting on daily measured physical activity and daily measured depressive symptoms. In the daily measure of behavior column the following words were selected: ‘physical activity’, ‘physical exertion’ and ‘steps’. In the daily measured mental health column, 'depression' was selected. This selection resulted in five articles. The second way was by selecting on daily measured physical activity and daily measured mood/ emotions. Daily physical activity was searched here in the same way as before. In the daily measured emotional column, ‘mood’, ‘PA and NA’, and ‘PANAS’ were selected. This selection was incorporated into the study due to the extensive research conducted on the influence of daily physical activity on PA and NA in relation to depressive symptoms. Including these studies adds valuable insights to this systematic review, enhancing the understanding of the intricate relationship between physical activity and affective states in the context of depression. This selection resulted in eighteen articles, sixteen of which had not yet appeared in the first search.

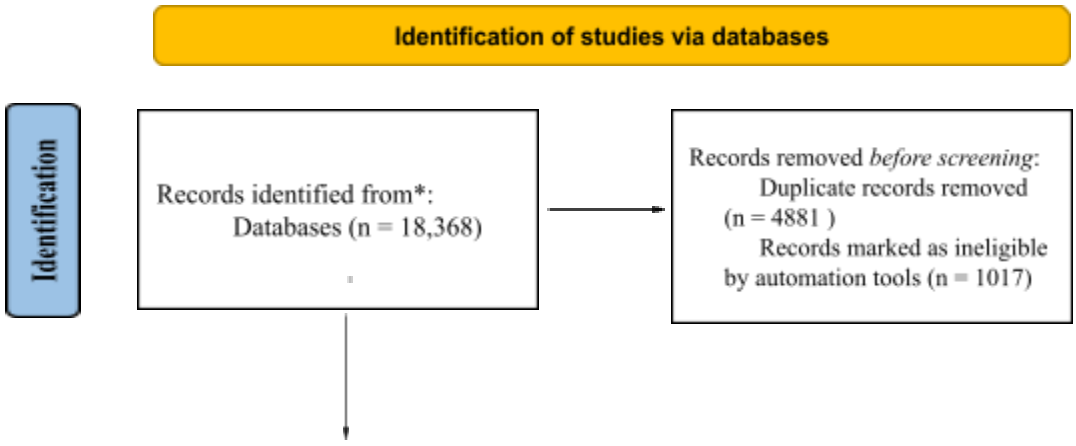
Results

Study selection

The identification of studies via the database is shown in a PRISMA diagram in figure 1. In total, a selection of twenty-one articles were selected from the database. Of these articles, one study was excluded due to age criteria, three studies were excluded for not measuring daily physical activity, and ten studies were excluded because they provided minimal information about the measured physical activity, particularly in relation to depressive symptoms. Ultimately, five studies from the database fit the inclusion criteria. This number of studies has been supplemented with five other studies using the snowball method. This means that more suitable articles were selected from the references of the already selected articles. Four articles have been selected from the references of research by Bos et al. (2018) and one article from references of the research by Poole et al. (2011). This gives the final ten articles included in this thesis.

Figure 1

PRISMA diagram for data exclusion



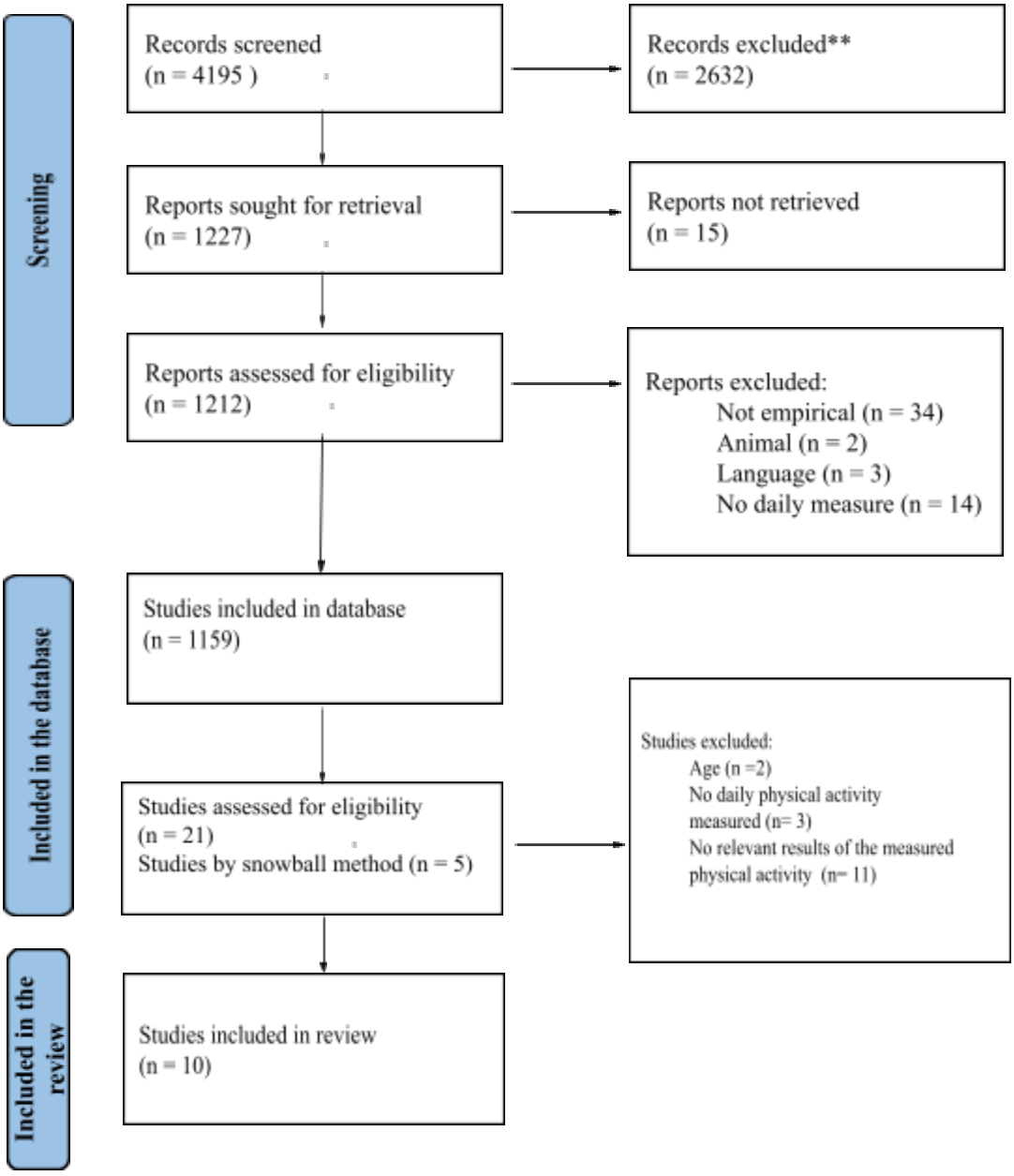


Table 1 presents the most relevant descriptive information of each study, while Table 2 displays the most relevant results. The bidirectionality column indicates whether the study's design evaluates both directions of the relation. A 'no' indicates that bidirectionality was not considered in the design, and therefore only one direction of the relationship was accounted for.

In this case, the specific direction of the relationship is noted. Conversely, a 'yes' means that bidirectionality was considered in the study's design. The outcome column shows whether a significant relationship is demonstrated in the study. A '+' denotes a significant relationship between physical activity and depressive symptoms, whereas a '-' indicates that the evidence for a relationship between the two factors is not significant.

Table 1

Descriptive information of the selected studies (n = 10)

Author (year)	Country	Source of participants	Range or mean age	Female %
Bermudez et al., (2022)	Switzerland	Clinical, cardiac patients	62	15,5
Bos et al., (2018)	The Netherlands	Depressed individuals with or without anhedonia	42	95
Cunningham et al., (2021)	United States	General	37	--
Fuller‐Tyszkiewicz et al., (2017)	Australia	General, university	30	71
Mata et al., (2012)	United States	MDD patients, control	27	70
Poole et al., (2011)	United Kingdom	General	29	100
Rosmalen et al., (2012)	The Netherlands	Clinical	56	0
Stavrakakis et al., (2015)	The Netherlands	Depressed individuals, control	37	70
Van Gool et al., (2003)	The Netherlands	Depressed individuals, control	55 -85	58
Wichers et al., (2012)	Belgium	General, twins	27	100

Table 2

Results of the selected studies (n = 10)

Author (year)	Sample size	Physical activity measured	Depressive symptoms measured	Frequency and duration of measurements	Bidirectionality	Estimate	P-value	Out-come
Bermudez et al., (2022)	129	Moderate to vigorous physical activity MVPA), light physical activity (LPA), sedentary behavior (SB)	Depressive symptoms; PHQ	Physical activity: all day (accelerometer). Depressive symptoms: one time a day. Duration: twenty-nine days	No Depressive symptoms → physical activity	MVPA[b]: r= -0.06 LPA[b]: r= -0.07 SB[b]: r= 0.04	MVPA: p < 0.01 LPA: p < 0.001 SB: p < 0.05	+
Bos et al., (2018)	40	Physical activity	Affect, depressive symptoms; QIDS-SR	Physical activity: three times a day. Depressive symptoms: three times a day. Duration: thirty days	No Physical activity → affect	PA: IRF[a] = 0.01 NA: IRF[a] = 0.17	-- --	-
Cunningham et al., (2021)	1504	Exercise, steps	Depressive symptoms; PHQ-9	Physical activity: one time a day. Depressive symptoms: one time a day. Duration: three days	No Physical activity → depressive symptoms	t= -1.844 95% CI: [-2.481; -1.201]	p <.001	+
Fuller‐Tyszkiewicz et al., (2017)	73	Low intensity activities, high intensity activities	Depressed mood; PHQ-9, POMS-SF	Physical activity: six times a day. Depressive symptoms: six times a day. Duration: seven days	No Physical activity → depressive symptoms	Beta[b]= -0.06 Beta[b]= -0.05 Beta[b]= -0.01	Lag[c] <2 hours: p= .046 Lag[c] 2-5 hours: p= .288 Lag[c] >5 hours:	+ - -

							p= .483	
Mata et al., (2012)	106	Physical activity; mild, moderate, strenuous activity	PANAS	Physical activity: eight times a day. PA and NA: eight times a day. Duration: eight days	No Physical activity → affect	t= -1.14 SE= 0.09 --	PA: p= 0.25 NA: p >.05	+ -
Poole et al., (2011)	40	Physical activity levels; sedentary, light, moderate, vigorous	Depressive symptoms; CES-D	Physical activity: one time per day for >10 consecutive hours. Depressive symptoms: one time a day. Duration: seven days	No Physical activity → depressive symptoms	Light activity[b]: r= -0.35 Moderate activity[b]: r= -0.37 Vigorous activity[b]: r= 0.14	Light activity: p <.05 Moderate activity: p <.05 Vigorous activity: --	+
Rosmalen et al., (2012)	4	Commuting activities; work activities; household activities; sports; leisure-time activities	Depressive symptoms; PHQ	Physical activity: one time a day. Depressive symptoms: one time a day. Duration: three months	Yes	IRF[a]: Participant 1: -0.183[b] Participant 2: -0.038[b] Participant 4: -0.041[b] Participant 5: -0.381[b]	 Participant 1: p= .03 Participant 2: p= -- Participant 4: p <.001 Participant 5: p_5= .04	+
Stavrakakis et al., (2015)	20	Energy expenditure	PA and NA	Physical activity: all day (accelerometer). PA and NA: three times a day (six hours in between). Duration: thirty days	Yes	NA[b]: t= 0.37 PA[b]: t= 0.89	NA: p >.05 PA: p >.05	+
Van Gool et al.,	1280	Minutes physical	Depressive symptoms;	Physical activity: one	Yes	Emerging depression:	--	+

(2003)		activity per day (adding up activities like walking, cycling, sport, and light and heavy household chores)	CES-D	time per day. Depressive symptoms: three times spread over six years. Duration: six years		RR[d] = 0.88 95% CI: [0,39; 1,98] Remitted depression: RR[d] = 2.06 95% CI: [0.84; 5.06] Persistent depression: RR[d] = 0.54 95% CI: [0.20; 1.50]	-- --	
Wichers et al., (2012)	504	Physical activity; resting, sitting, walking, household chores, biking, playing tennis, running	PANAS	Physical activity: ten times a day. Depressive symptoms: ten times a day. Duration: five days	No Physical activity → affect	PA: Cronbach's Alpha= 0.75 Effect size[e]: 0.119 NA: Cronbach's Alpha= 0.53 Effect size[e]= 0.000	PA: p <.001 NA: p= .987	+

Note. MVPA = moderate to vigorous physical activity; LPA = light physical activity; SB = sedentary behavior; PA = positive affect; NA = negative affect; SE = standard error.
[a] An impulse response function (IRF) is a statistical method used to analyze the dynamic response of one or more variables (in this case, affect) in a vector autoregression model to a one-time change in another variable (in this case, physical activity). [b] No credibility measured. [c] Lag indicates how long after the increase in physical activity the effect was measured. [d] Relative Risk ratio. [e] No specific type of effect size.

Demographic characteristics

The demographic characteristics of participants are summarized in Table 1. All participants are aged 18 and older, with mean ages ranging from 27 to 85 years. The majority of the participants are female. Further demographic details, such as country and source of participants are also included to offer an overview of the participant profiles.

Bidirectional studies

Significant bidirectional effects have been found in the relationship between physical activity and depressive symptoms (Rosmalen et al., 2012; Stavrakakis et al., 2015). Among the four participants in research by Rosmalen et al. (2012), one showed a significant effect of physical activity on reducing depression, while two participants exhibited significant effects in the opposite direction. This indicates that experiencing depressive symptoms might lead to reduced physical activity, and conversely, engaging in less physical activity could be linked to an increase in depressive symptoms, highlighting the bidirectionality of this relationship (Rosmalen et al., 2012; Stavrakakis et al., 2015; Van Gool et al., 2003).

However, individual differences in the direction of the relationship were noted (Rosmalen et al. 2012). The bidirectional relationship, as indicated by some studies, was not evident in the individuals. The direction of the relationship between physical activity and depressive symptoms differs from person to person. The association is present in both directions, but not simultaneously in the same individual.

Furthermore, non-depressed individuals were physically active for an average of 20 minutes longer per day compared to depressed individuals (Van Gool et al., 2003). Individuals who began developing depressive symptoms tended to adopt a sedentary lifestyle, engaging in up to 45 minutes less physical activity per day. Conversely, those who recovered from depression became more physically active compared to the healthy control group.

Unidirectional studies

Building on this understanding of bidirectionality, several studies have specifically examined the unidirectional relationship between physical activity and depressive symptoms (Cunningham et al., 2021; Fuller‐Tyszkiewicz et al., 2017; Poole et al., 2011). These studies focused on the effect of physical activity on depressive symptoms and demonstrated a significant

effect. Their findings consistently indicate that increased physical activity is associated with lower levels of depressive symptoms.

Research by Fuller‐Tyszkiewicz et al. (2017) found that physical activity predicted changes in depressive symptoms, but only when examined within a two-hour time delay. When the time between measurements increased, the association was no longer significant. These results were consistent across individuals, indicating that the observed patterns were evident both in the overall sample and at the individual level.

The intensity of physical activity is also important in this association (Poole et al., 2011). There is a correlation between light and moderate physical activity with depressive symptoms as measured by the CES-D scale. However, there was no significant association between vigorous physical activity and the CES-D scores.

Other research has examined the unidirectional relation between depressive symptoms and physical activity (Bermudez et al., 2022), specifically focusing on the impact of depressive symptoms on physical activity. Individuals with higher levels of depressive symptoms tend to engage in less physical activity (Bermudez et al., 2022; Van Gool et al., 2003). This trend is evident even when considering low physical activity (LPA), which is lower among individuals with depressive symptoms (Bermudez et al., 2022). Notably, even those with lower levels of depressive symptoms show a significant reduction in LPA. It showed that for each unit increase in depressive symptoms, total LPA per day decreases by approximately 37 minutes.

Affect

Several studies have examined depressive symptoms in terms of affect (Bos et al., 2018; Mata et al., 2012; Stavrakakis et al., 2015; Wichers et al., 2012). Bos et al. (2018) considered affect as a whole and found that physical activity had a weak influence on it. In fact, their study

suggests that physical activity may negatively impact affect rather than improve it. However, contrary to Fuller‐Tyszkiewicz et al. (2017) who focused on depressive symptoms, significant individual differences exist within this relationship when considering affect (Bos et al., 2018).

Other studies have examined NA and PA separately. They found no significant association between physical activity and NA (Mata et al., 2012; Stavrakakis et al., 2015; Wichers et al., 2012). This applies to both depressed individuals and healthy individuals (Mata et al., 2012). However, a significant effect was observed between PA and physical activity within three hours after the increase in physical activity (Wichers et al., 2012). Other research indicates that some individuals demonstrated an effect even after a longer duration of six hours (Stavrakakis et al., 2015). No difference was found in the increase in PA between the groups of depressed and healthy individuals.

Discussion

This systematic review includes ten studies that examined the relationship between daily physical activity and depressive symptoms in adults. The findings highlighted a complex interplay between physical activity and depression, underscoring both bidirectional and unidirectional associations, as well as nuanced effects on affect.

Consistent with previous research, this review confirmed significant bidirectional effects between physical activity and depressive symptoms (Rosmalen et al., 2012; Van Gool et al., 2003). Studies revealed that individuals with higher depressive symptoms tend to engage in less physical activity (Bermudez et al., 2022), while reduced physical activity can also exacerbate depressive symptoms (Rosmalen et al., 2012; Stavrakakis et al., 2015; Van Gool et al., 2003). This highlights the complex interplay between daily physical activity and depressive symptoms. However, this review has provided new insights, revealing that there are individual differences in

the direction of the relationship. The association is present in both directions, but not simultaneously in the same individual (Rosmalen et al., 2012). Individual differences were not further explored in this review, but existing research suggests that various moderating factors, such as age, gender, activity intensity, and severity of depressive symptoms, influence the connection (Schuch et al., 2016). Indeed, this research indicates that the intensity of physical activity is important, with light and moderate activity correlating with lower levels of depressive symptoms, while heavy physical activity shows no significant association (Poole et al., 2011).

Additionally, several studies have examined the unidirectional relationship between physical activity and depressive symptoms, with many demonstrating a significant effect of physical activity on reducing depressive symptoms (Cunningham et al., 2021; Fuller‐Tyszkiewicz et al., 2017; Poole et al., 2011). Increased physical activity was associated with lower levels of depressive symptoms, highlighting the potential of physical exercise as a therapeutic intervention for mild to moderate depression (Fuller‐Tyszkiewicz et al., 2017). This aligns with existing research suggesting that physical activity could be comparably effective to antidepressant medication in reducing mild to moderate depressive symptoms (Gujral et al., 2017; Hallam et al., 2022; Van Gool et al., 2003).

The inclusion of research that investigated NA and PA separately adds further depth to our understanding of the relationship between daily physical activity and depressive symptoms. Interestingly, several studies did not find a significant association between physical activity and NA, regardless of the participants' depressive symptomatology (Mata et al., 2012; Stavrakakis et al., 2015; Wichers et al., 2012). This finding suggests that the impact of physical activity on depressive symptoms may not be mediated through changes in NA. However, some other studies did find a significant effect when looking at the impact of physical activity on PA (Mata et al.,

2012; Wichers et al., 2012). This suggests that the relationship between physical activity and depressive symptoms may vary depending on specific affective components. According to previous research, individuals experiencing depression typically exhibit increased NA alongside a decrease in PA, which are common indicators of depression (Bos et al., 2018; Wichers et al., 2012). The significant findings that physical activity can increase PA (Stavrakakis et al., 2015; Wichers et al., 2012), may explain the improvement in depressive symptoms in these individuals. Previous studies have highlighted that while much attention has been given to NA in depressed individuals, PA is also of significant interest (Bos et al., 2018; Mata et al., 2012). The significant findings regarding PA in this study align with these earlier insights. Thus, contrary to previous research, it is interesting for future studies to focus more on PA when exploring the reduction of depressive symptoms. However, individual differences play a crucial role in this relationship (Bos et al., 2018), suggesting the relevance of further exploring the causes behind these individual variations.

This study highlights the importance of the temporal aspects of the relationship. Several studies examining depressive symptoms themselves, as well as depressive symptoms in terms of affect, indicate the importance of timing. It was found that physical activity predicted changes in depressive symptoms, but only when examined within a two-hour time delay (Fuller‐Tyszkiewicz et al., 2017). When considering affect, a significant effect was observed between physical activity and PA within three hours after the increase in physical activity (Wichers et al., 2012). However, other research indicates that some individuals demonstrated an effect even after a longer duration of six hours (Stavrakakis et al., 2015). This highlights the variability of the effects observed in different studies over different time periods.

Limitations and strengths

Interpreting the results of this review requires caution due to several limitations. A first limitation pertains to the varying methodological quality observed across the included studies, which may impact the consistency of the results. Some studies have relied on self-reported measures of physical activity and depressive symptoms, while others have utilized more objective assessments. In addition, the frequency and duration of measurements varied between studies, which could potentially influence the observed effects, particularly with regard to the temporal aspects of the relationship. Furthermore, the interpretation of physical activity varied between studies. The interpretation of the construct refers to how researchers analyze and present the data collected in relation to the research question and theoretical framework of the study. While some studies considered the intensity of activity, others did not. In addition, different studies focused on different aspects of physical activity, such as general exercise, number of steps or movement in daily activities. These different interpretations may lead to different conclusions.

Another limitation contains the inconsistent demographic characteristics among the studies' participants. The majority of the studies predominantly involved female participants, with only one study focusing exclusively on men. This could potentially constrain the generalizability of the findings, considering that gender may influence the relationship. Also, the studies were conducted across different countries, which introduces the possibility of cultural variations affecting the relationship.

Included in this review are studies that directly examine the relationship between physical activity and depressive symptoms, as well as those that explore the impact of physical activity on PA and NA related to depressive symptoms. This inclusion may be another limitation, as it introduces a difference in the measured constructs, namely depressive symptoms and affect. This

may also account for the observation that significant effects were primarily found when examining physical activity and depressive symptoms, whereas the effects of physical activity on affect as a whole were less pronounced. Significant effects between physical activity and affect emerged only when PA and NA were analyzed separately. It is also notable that individual differences varied between the two constructs. For depressive symptoms, individual differences were found only in the direction of the association and not in the relationship itself. For PA and NA, however, variation was observed within the context itself.

There are also limitations regarding the method of this review. Achieving uniformity among a group of twelve different coders is challenging. Each factor may have numerous synonyms, leading to various ways of indicating the same factor in the database. Furthermore, one coder might categorize a factor under "stress", while another might place the same factor under "mental health", making consistency in operationalization difficult to achieve. Additionally, not all articles could be included due to issues such as language barriers or restricted access, with some articles only accessible through paid sites.

However, this review methodology also has several strengths. The use of ambulatory assessment contributes substantially to ecological validity. Data collected in participants' real-life settings ensures that the findings are more likely to reflect real-life scenarios rather than artificial laboratory settings. In addition, the use of systematic review methodology adds strength through its strong evidence base. By synthesizing the results of several studies, it provides a comprehensive overview and makes it easier to identify patterns or inconsistencies in the results. Furthermore, as mentioned previously, the inclusion of daily measurements of physical activity increases the accuracy of the results and thus strengthens the power of this review.

Follow-up research

Looking ahead, there are several directions for future research to extend the findings of this systematic review on the association between daily physical activity and depressive symptoms in adults. First, given the complexity and variability observed in the associations between physical activity and depression, future studies should focus on clarifying the underlying mechanisms that contribute to these associations. Understanding why and how physical activity affects depressive symptoms differently in different individuals could provide valuable insights for personalized interventions.

In addition, given the impact of individual differences, future research should investigate specific moderating factors that may influence the relationship between physical activity and depressive symptoms. Factors such as age, gender, activity intensity and severity of depressive symptoms have been identified as potential moderators in previous studies (Schuch et al., 2016). Further research into how these factors interact could help to tailor interventions more effectively to different demographic and clinical groups.

There is also a need for longitudinal studies that track the effects of physical activity on depressive symptoms over time, taking into account immediate and delayed effects. The temporal aspect emerged as significant in several studies included in this review, suggesting that the timing of physical activity in relation to depressive symptoms may influence its effectiveness (Fuller-Tyszkiewicz et al., 2017; Stavrakakis et al., 2015; Wichers et al., 2012). Longitudinal designs could clarify whether there are optimal windows during which physical activity is beneficial for reducing depressive symptoms.

In addition, future research should address the methodological limitations identified in this review. Ensuring methodological consistency, such as using standardized measures and uniform operational definitions across studies, could improve the comparability and reliability of

findings. Addressing these limitations would strengthen the evidence base and improve our understanding of the relationship between physical activity and depressive symptoms.

Implications

The results of this systematic review have several implications for practice and policy. Firstly, they indicate the potential of physical activity as a therapeutic intervention for the reduction of depressive symptoms, particularly mild to moderate depression. Incorporating physical activity into treatment plans could provide a non-pharmacological approach to complement existing therapies.

In addition, the recognition of individual differences suggests that interventions should be personalized to account for different responses to physical activity in different demographic and clinical groups. Tailoring physical activity programmes to factors such as age, gender and activity preferences could increase their effectiveness in reducing depressive symptoms.

Although much remains to be discovered, it appears that physical activity is generally beneficial and at least not harmful. Therefore, policy makers and health care providers should consider promoting physical activity as a preventive measure against depression, as it may act as a buffer against the development of depressive symptoms. Implementing initiatives to promote regular physical activity among adults may potentially contribute to reducing the burden of depression in the population.

Conclusion

This systematic review has aimed to answer the research question: "What is the relationship between daily physical activity and depressive symptoms in adults?" To achieve this, a comprehensive analysis of the existing studies in this area has been carried out.

This systematic review has found many complex and variable relationships between daily physical activity and depressive symptoms. One study has found no difference in physical activity between depressed and healthy individuals, while other studies have shown that higher levels of depressive symptoms are associated with less physical activity, both moderate-to-vigorous and low. Additionally, physical activity has often seemed to act as a buffer against depressive symptoms, with greater activity being associated with lower levels of these symptoms. The intensity and timing of physical activity have played an important role in this relationship. Individual differences have also been found in the strength and direction of these associations, suggesting that the effect of physical activity on depressive symptoms is not uniform for everyone. For affect, the results have been mixed. For overall affect, a weak influence of physical activity has been found. However, while some studies have found no significant association between physical activity and NA, an increase in PA has been observed after physical activity. Timing has been crucial, with physical activity affecting depressive symptoms within two hours and PA within three hours, although some effects have persisted for up to six hours.

The findings have highlighted the importance of considering individual and temporal factors in future research and interventions. The complexity and variability in these associations have underscored the need for nuanced approaches in developing effective strategies. Policies and programs promoting physical activity to alleviate depressive symptoms should account for individual differences in responsiveness. Future research should focus on identifying the underlying mechanisms of these variations to develop personalized strategies that maximize the benefits of physical activity in reducing depressive symptoms.

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