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PHYSICAL ACTIVITY AND MENTAL HEALTH: A SYSTEMATIC REVIEW

Laia Maynou
Center for Research in Health and Economics (CRES), Universitat Pompeu Fabra
London School of Economics and Political Science, Health Policy
Research Group on Statistics, Econometrics and Health
CIBER of Epidemiology and Public Health (CIBERESP)

Helena M. Hernández-Pizarro
Center for Research in Health and Economics (CRES), Universitat Pompeu Fabra
TecnoCampus, Universitat Pompeu Fabra

Marlene Herisson
Center for Research in Health and Economics (CRES), Universitat Pompeu Fabra

Marc Saez
Research Group on Statistics, Econometrics and Health
CIBER of Epidemiology and Public Health (CIBERESP)
Center for Research in Health and Economics (CRES), Universitat Pompeu Fabra

Barcelona

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PHYSICAL ACTIVITY AND MENTAL HEALTH: A SYSTEMATIC REVIEW

Maynou, L.[1,2,3,4], Hernández-Pizarro, H.M.[1,5], Herisson, M.[1], Saez, M. [3,4,1]

[1]*Center for Research in Health and Economics (CRES), Universitat Pompeu Fabra*

[2]*London School of Economics and Political Science, Health Policy*

[3]*Research Group on Statistics, Econometrics and Health*

[4]*CIBER of Epidemiology and Public Health (CIBERESP)*

[5]*TecnoCampus, Universitat Pompeu Fabra*

Abstract

Mental disorders are leading causes of ill-health and disability worldwide. Various factors influence mental health, such as lifestyle (diet, sport, alcohol and drug consumption), social environment/context, work conditions, family background and individual characteristics. This study focuses on lifestyle and, in particular, in the effects of physical activity. Numerous international health organisations have outlined the benefits of physical activity in reducing the risk of physical and mental illnesses. The objective of this paper is to conduct a rigorous systematic review on the relationship between physical activity and mental health. Through the analysis of 51 studies, we provide an overview, a comparison and a summary the main findings of this association. We also identify research gaps and priorities for further study. We find a positive relationship between physical activity and mental health. As a result, physical activity interventions may serve as a cost-effective mean to promote physical and mental health, as it also facilitates mental development.

Key words: physical activity, mental health, green spaces, team sport.

1. Introduction

Mental disorders are leading causes of ill-health and disability worldwide. They hit around 450 million people and one out of four people in the world is or will be affected by mental or neurological disorders at some point in their lives (WHO, 2001). Indeed, this type of disorder are the third leading cause of disability-adjusted life years (DALY) in Europe (WHO, 2014). Mental health has been defined by the WHO as "a state of well-being in which every individual realises his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community" (WHO, 2014).

Various factors influence mental health, such as lifestyle (diet, sport, alcohol and drug consumption), social environment/context, work conditions, family background or individual characteristics. Within these factors, in this study, we focus on lifestyle and, in particular, in the effects of physical activity. As defined by WHO (2018a), physical activity can be undertaken in many different ways: walking, cycling, sports and active forms of recreation (for example, dance, yoga, tai chi). Physical activity can also be undertaken at work and around the home. Numerous health organisations (CDC, WHO, Health and Human Services) have outlined the benefits of physical activity. Apart from the fact that physical inactivity is a truly global problem, estimated to be responsible for more than 5.3 million deaths each year (Murray et al. 2016), it can reduce the risk of mental illnesses. This is link to the fact that physical activity can improve physical health, self-stem and quality of life, which in turns enhance wellbeing and mental health. Therefore, recommendations have been provided for the minimum amounts of activity for all age groups: 60 minutes of moderate- to vigorous-intensity physical activity daily for youth and 150 minutes of moderate-intensity aerobic physical activity throughout the week for adults and elderly (WHO, 2018b). Yet, 25% of adults and 75% of teenagers do not meet these recommendations (2018a).[1]

[1] Teenagers as individuals aged between 11 and 17 years old.

Not only international health organisations have been interested in the relationship between physical activity and mental health, but also academics, as previous literature show. In a recent paper, Zhang *et al.* (2015) used econometric models to state that physical activity ameliorates depressive symptoms among mildly and moderately depressed individuals. Lordan *et al.* (2014) also confirmed these results and add that the impact is higher for women. Moreover, it has been also analysed by different categories such as green spaces, group exercise, elderly, youth, gender and countries/regions and the characteristics of the activity including development in green space or in groups. For example, for Mitchell (2013) physical activity in natural environments is associated with a reduction in the risk of poor mental health while, according to Marselle *et al*. (2013), the group-walks in specific types of natural environments are associated with greater psychological and emotional well-being. Moreover, for Ho *et al.* (2015), physical activity improves adolescent mental health.

However, even if the approach differs with the studies, one of the main common findings is that regular physical activity is known to prolong life expectancy and positively impact on many physical and mental health conditions. Physical activity might be an effective measure for the prevention and treatment of psychiatric diseases. Actually, psychotropic medications remain at the front line of treatment for affective disorders. However, a growing body of scientific evidence strongly supports the role of exercise in the treatment of these affective disorders (Zschucke *et al*, 2013).

This paper reviews the existing literature that explores the relationship between physical activity and mental health. The objective is to conduct a rigorous systematic review providing an overview, comparing and summarising the main findings of this association. In particular, we analyse 47 studies. The main result of this paper is that there is a positive relationship between physical activity and mental health. As a result, we claim that physical activity interventions may serve as a cost-effective means to promote physical and mental health, as it facilitates mental development. Moreover, we also identify research gaps and priorities for further study. In particular, the causal link between physical activity and mental health due to endogeneity.

This paper is organised as follows. In Section 2 we present the methodology. In Section 3, the results are presented. Finally, Section 4 presents the discussion.

2. Methods

In this paper, a systematic literature review is done in order to provide evidence on the relationship between physical activity and mental health. A systematic review provides a comprehensive and rigorous approach in assessing the available literature. We follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[2] checklist in order to conduct the systematic review.

We proceed in two stages. First of all, we identify relevant studies and, secondly, we analyse the studies selection.

Stage 1: Identify relevant studies

Step 1: Initial search. To identify studies that assess the association between physical activity and mental health, we explore at three databases. In particular, EconLit, MedLine and PubMed were consulted for articles released from 2000 until June 2018. The key words used were “physical activity”, "mental health”, “mental well-being”, “sport”, “walking”, “lifestyle”, “green space”, “green exercises”, “exercising in group”,” nature”. This gave us nineteen combinations.

We added, like Eime *et al*. (2013), some eligibility criteria which correspond to the criteria needed to determine the appropriate articles for the systematic review’s references. They are divided in two types: inclusion (what we want in the review) and exclusion criteria (what we do not want)

Inclusion criteria:

- All forms of physical activity and mental health
- Only human based studies
- All age groups and both sexes of participants.

[2] http://www.prisma-statement.org

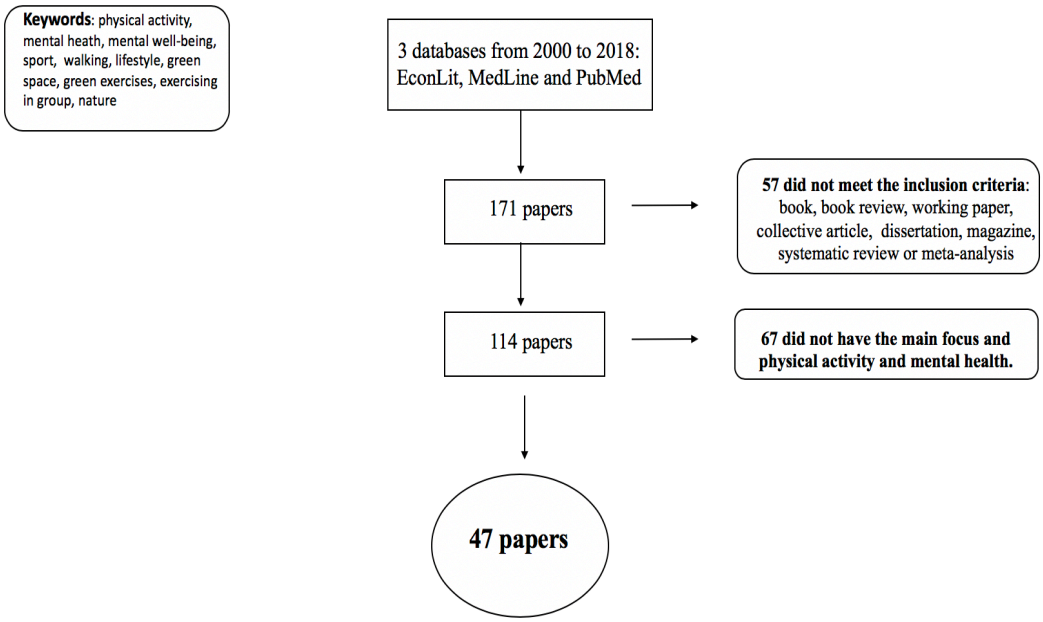
- Research articles are not limited by geographical location

Explicit exclusion criteria:

- Book, book review, working paper, collective volume article[3], dissertation, magazine, systematic review.
- Articles in a language other than English

Step 2: Coherence of papers. The final search identified 171 records (duplicates removed). After initial title and abstract screening an additional 124 records were excluded for the following reasons: did not meet inclusion criteria (57 abstracts), systematic reviews or meta-analyses (10 abstracts) and did not have the main focus on physical activity and mental health relationship (67 abstracts). This left a remaining 47 abstracts for full text review which were included in the systematic review. These papers were classified as following: 7 statistical papers and 40 econometric papers. Figure 1 presents the procedure followed for the papers considered finally.

Figure 1: Summary of the systematic review



[3] Collection of chapters contributed by different authors and harmonised by an editor

Stage 2: Examine of the study selection

Articles suggested by the search strategy had been evaluated by one reviewer. Moreover, two other reviewers have assessed the titles and abstracts in order to ensure of the coherence of our list of references.

Regarding the risk of bias assessment, we followed the method developed by Parmar *et al.* (2016). They assessed the risk of bias of the included studies over seven key domains of bias: selection bias, ecological fallacy, confounding bias, reporting bias, time bias, measurement error in exposure indicator, and measurement error in health outcome. Studies were given a rating for each domain, with each scored as 1 (strong; low risk of bias), 2 (moderate; moderate risk of bias), or 3 (weak; high risk of bias). An overall rating for each study was based on the rating of each domain. A study was given an overall rating of 1 (strong) if none of its domains was rated as weak; 2 (moderate) if up to two domains were rated as weak; and 3 (weak) if three or more domains were rated as weak (Parmar *et al.*, 2016).

3. Results

The result of the search gave us 47 papers looking at the relationship between physical activity and mental health. For a better comparison, we have classified them in two groups: statistical and econometrics papers. In this section, we analyse these groups of papers. The main goal is to summarise the main results and compare across them. In each group, we also distinguish the papers into the following categories: 1) lifestyle, 2) physical activity volume, 3) depressive symptoms and perceived stress, 4) natural environments, 5) age and gender of individuals and 6) team sport.

However, first of all, before analysing in detail each paper, we present two previous analyses: the risk assessment (Table 1) and the main indicators used to define mental health and physical activity (Tables 2 and 3).

3.1. Papers risk assessment

Regarding the risk assessment (Annex: Table A), of the 47 studies we reviewed (i.e. statistical and econometric papers), only one study (2%) was rated as weak, showing a high risk for bias in at least three domains. Thirty-six studies (77%) were rated as moderate, showing a high risk for bias in up to two domains. And ten studies (21%) were rated strong in the overall risk assessment. Most of the studies were rated weak in the time bias category. Many studies were also at a high risk of measurement bias in exposures and in health outcome.

3.2. Indicators for Physical Activity and Mental health

The literature on physical activity and mental health is based on numerous indicators (Table 1). For physical activity, the most used indicators are:

- *Moderate-to-vigorous physical activity (MVPA)*, assessed by combing two questions: 'how many days during a typical week did you exercise moderately for at least 30 minutes?' and 'how many days during a typical week did you exercise vigorously for at least 20 minutes?

- *Euroqol EQ-5D (2005) questionnaire* which provides a simple descriptive profile and a single index value for health status. The five dimensions in the EQ-5D are mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension provides three options of response: no problems, some problems and extreme problems.

- *Physical Activity Scale for the Elderly (PASE)*, a 12-item scale for estimating physical activity in older adults, and includes separate assessment of leisure-time activity (5 items: walking, light/moderate/strenuous sport and recreational activities, and muscle strengthening exercise), household activity (6 items: light housework, heavy house chores, home repairs, lawn work/yard care, outdoor gardening, and caring for another person), and work-related activity (1 item: working for pay or as volunteer).

- *International Physical Activity Questionnaire (IPAQ-short)*, a set of 4 questionnaires with 4 generic items that assesses the types of intensity of physical activity and sitting time that people do as part of their daily lives are considered to estimate total physical activity in MET-min/week and time spent sitting.

On the other hand, for mental health, the most used indicators are:

- *General Health Questionnaire (GHQ)*, the industry standard for measuring psychological health and consists of questions regarding the respondent's emotional and behavioural/psychosocial health over the past few weeks.

- *Perceived Stress Scale (PSS)*: participants were asked to rate the frequency of experiencing certain thoughts and feelings in the past two weeks on a 5-point scale.

Table 1: Physical Activity and Mental Health Indicators (Econometrics, Statistical Papers)

Physical Activity Indicators	**Papers**
Physical activity index (PAI)	Galper *et al.* (2006)
Todai Health Index (THI)	Tuekpe *et al.* (2006)
Cumulative Lifestyle Index (CLI)	Tuekpe *et al.* (2006)
Euroqol EQ-5D (2005) questionnaire	Pretty *et al.* (2007), Forbes *et al.* (2017)
Physical Activity Scale for the Elderly (PASE)	Kwag *et al.* (2011), Ku *et al.* (2014)
BRFSS questionnaire	Zhang *et al.* (2015)
Activities of Daily Living (ADL)	Ohrnberger *et al.* (2017a, 2017b)
Youth Risk Behavior Survey	Van Kim and Nelson (2013)
International Physical Activity Questionnaire (IPAQ-short)	Richards *et al.* (2015), Dadvand *et al.* (2016)
RAND	Kuvaja-Kollner *et al.* (2013)
Self-reported Physical Activity	Pasanen *et al.* (2014)
Moderate-to-vigorous physical activity (MVPA)	Cohen-Cline *et al.* (2016), Buman *et al* (2010)

Mental Component Summary score (MCS-12)	Ho *et al.* (2015),
Physical Activity Rating Questionnaire for Children and Youth (PARCY)	Miller and Hoffman (2009)
Short Form–12 (SF-12) health scale	Withall *et al.* (2014)
EPIC-Norfolk Physical Activity Questionnaire	Triguero-Mas *et al.* (2015)
Physical Component Summary score (PCS-12)	Kuvaja-Kollner *et al.* (2013)

Mental Health Indicators	**Papers**
Center for Epidemiologic Studies Depression Scale (CES-D)	Galper *et al.* (2006), Ohrnberger et al. (2017a, 2017b), Miller and Hoffman (2009)
General Well-Being Schedule (GWB)	Galper *et al.* (2006)
Todai Health Index (THI)	Tuekpe *et al.* (2006)
Cumulative Lifestyle Index (CLI)	Tuekpe *et al.* (2006)
Geriatric Depression Scale (GDS)	Kwag *et al.* (2011), Benedetti *et al.* (2008)
Profile of Mood States (POMS) scale	Yuenyongchaiwat (2016), Pretty *et al.* (2007), Barton *et al.* (2005), Barton and Pretty (2010)
General Health Questionnaire (GHQ)	Pretty *et al.* (2007), Barton *et al.* (2005), Lordan *et al.* (2014), Steinmo *et al* (2014), Mitchell (2013), Griffiths *et al.* (2014), Triguero-Mas *et al.* (2015), Hamer *et al.* (2009), Dadvand *et al.* (2016), Asztalos *et al.* (2009b)
Rosenberg Self-Esteem Scale (RSE)	Pretty *et al.* (2007), Barton *et al.* (2005), Barton and Pretty (2010)
State Trait Inventory for Cognitive and Somatic Anxiety (STICSA)	Lawton *et al.* (2017)
Psychological Well-Being Scale (PWB)	Lawton *et al.* (2017)
Kessler 10 scale (K10)	Astell-Burt *et al.* (2013), Ambrey (2016)
Warwick Edinburgh Mental Well-being Scale (WEMWBS)	Marselle *et al.* (2013), Harris (2018), Mitchell (2013), Black *et al.* (2015)
Major Depressive Inventory (MDI)	Marselle, *et al.* (2013)

Perceived Stress Scale (PSS)	Marselle, *et al.* (2013), Kwag *et al.* (2011), Van Kim and Nelson (2013), Cohen-Cline *et al.* (2016), Asztalos *et al.* (2009a)
Patient Health Questionnaire Depression Scale (PHQ-8)	Zhang *et al.* (2015), Cohen-Cline *et al.* (2016)
Short Form–36 (SF-36) health scale	Van Kim and Nelson (2013), Steinmo *et al.* (2014), Richards *et al.* (2015), Richardson *et al. (2013)*, Triguero-Mas *et al.* (2015)
Mental health inventory (MHI-5)	Sturm and Cohen (2014)
RAND	Kuvaja-Kollner *et al.* (2013)
Brief Symptom Inventory (BSI)	Cohen-Cline *et al.* (2016)
Positive Affect and Negative Affect (PANAS)	Marselle *et al* (2015), Parker *et al.* (2008)
Mental Component Summary score (MCS-12)	Ho *et al.* (2015), Kuvaja-Kollner *et al.* (2013)
Satisfaction With Life Scale (SWL)	Parker *et al.* (2008), Withall *et al.* (2014)
Short Form–12 (SF-12) health scale	Withall *et al.* (2014)
Life Satisfaction Index A (LSIA)	Ku *et al.* (2016)
Center for Epidemiologic Studies Depression (CESD)	Torres *et al.* (2014)
Heart Health Survey (WHHS)	Triguero-Mas *et al.* (2015)

3.3. Statistical papers

We had seven statistical papers in our references. We differentiated them from the econometric papers because they do not use an econometric model, but they make use of statistical techniques to establish associations. Table 2 summarises the methods used.

Table 2: Methods of statistical papers

Statistical Methods	Papers
Intervention (before/after) – mean difference	Barton *et al.* (2005), Pretty *et al.* (2007)
ANCOVA (means difference testing)	Galper *et al.* (2006)
MANOVAS	Lawton *et al.* (2017)
ANOVA	Harris (2018), Marselle *et al*. (2013)
Meta-analysis	Barton and Pretty (2010)

We divide the analysis by categories. The question of volume of physical activity was discussed by Galper *et al.* (2006) who evaluated the associations between measures of physical activity and mental health between 6728 men and women who completed a maximal fitness treadmill test and self-report measures of habitual physical activity, depressive symptoms and emotional well-being. They found that a significant inverse graded dose-response relationship increased with a walk or run of 11–19 miles per week.

Green exercise, public and environmental health consequences were tackled by Barton *et al.* (2005). They investigated whether there was a synergistic benefit in adopting physical activities whilst being directly exposed to nature. For that, five groups of 20 subjects were exposed to a sequence of 30 scenes projected on a wall whilst exercising on a treadmill. Results suggested that both rural and urban pleasant scenes produced a significantly greater positive effect on self-esteem than the exercise-only control. In 2007, Pretty *et al.* (2007) measured the effects of 10 green exercise case studies (including walking, cycling, horse-riding, fishing, canal-boating and conservation activities) on 263 participants. Results stated that green exercise led to a significant improvement in self-esteem and total mood disturbance. Self-esteem and mood were found not to be affected by the type, intensity or duration of the green exercise. Finally, Barton and Pretty (2010) tried to find the best dose response of nature and green exercise by a multi-study analysis involving 1252 participants. Results confirmed that the environment provides an important health service: every green environment improved both self-esteem and mood and the presence of water generated greater

effects. According to Lawton *et al.* (2017), the main benefit was that somatic anxiety is lower for outdoor physical activity.

Our last category for the statistical papers is team sport or exercising in groups. Marselle *et al.* (2013) investigated, by a cross-sectional design, whether group walks in specific types of natural environments were associated with greater psychological and emotional well-being compared to group walks in urban environments. Results showed that group walks in farmland were significantly associated with less perceived stress and greater mental well-being. This was also treated by Harris (2018) who examined the relationship between physical activity and mental well-being pre/post a community-wide, gamification-based intervention. Results revealed that increase in mental well-being was significantly greater for the least active prior to the intervention.

Our statistical references enable us to conclude that physical activity is the major lifestyle factor for a good mental health, improving quality of life, psychosocial function, and functional abilities and have a positive effect on self-esteem. The benefits of physical activity are increased by green space activities, which decrease anxiety, and exercising in group whatever the age of the participant. Indeed, physical activity predicted lower levels of fatigue among older adults.

3.4. Econometrics papers

We had forty econometrics papers in our references looking at the relationship between physical activity and mental health. To enter into the "econometric" category, papers had to use an econometric model to create the association. We found different types of econometric models depending on the data used and the research question of each paper. However, the main econometric technique used in our references is the logistic regression model. Table 3 summarises the main models used by these papers.

Table 3. Methods of econometrics papers

Econometric Model	Papers
Linear and multiple regression	Lordan *et al.* (2014), Parker *et al.* (2008), Ku *et al.* (2014, 2016), Black *et al.* (2015), Sturm and Cohen (2014), Miller and Hoffman (2009), Withall *et al.* (2014), Yuenyongchaiwat (2016), Tuekpe *et al* (2006)
Probit model	Lee and Park (2010), Rasciute and Downward (2010)
Logistic regression model	Van Kim and Nelson (2013), Richards *et al.* (2015), Mitchell (2013), Astell-Burt *et al.* (2013), Benedetti *et al.* (2008), Griffiths *et al.* (2014), Torres *et al.* (2014), Triguero-Mas *et al.* (2015), Goodwin (2003), Hamer *et al.* (2009), Dadvand *et al.* (2016), Asztalos *et al.* (2009a,b), Forbes *et al.* (2017)
Latent growth curve	Steinmo *et al* (2014)
Mixed-effects and Multilevel model	Cohen-Cline *et al.* (2016), Richardson *et al.* (2013), Marselle *et al.* (2015), Buman *et al.* (2010)
Path model	Ho *et al.* (2015)
Ordered switching/choice probability model	Downward and Rasciute (2011), Zhang *et al.* (2015)
Cluster-specific fixed model	Ambrey (2016)
Instrumental variables	Kuvaja-Kollner *et al.* (2013), Downward and Dawson (2016)
Structural equation modelling	Kwag *et al.* (2011), Pasanen *et al.* (2014)
Dynamic model	Ohrnberger *et al.* (2017a, 2017b)

The main result of these econometric studies is that greater physical activity is associated with better mental health. Regarding lifestyle, Ku *et al*. (2016) showed that engaging in leisure-time physical activity (LTPA) provide beneficial effects on mental health. Moreover, Kuvaja-Kollner *et al.* (2013) emphasised that the motivation or extra time (i.e. retirement) increase the time spent on physical exercise and as a consequence provides better health outcomes. In this line, Hamer *et al.* (2009), stated

that mental health benefits were observed at a minimal level of at least 20 min/weeks of any physical activity. However, Lordan *et al.* (2014) suggested a minimal level of 30+minutes or at least 10,000 steps over a week (Yuenyongchaiwat, 2016). Richards *et al.* (2015) stated that the association between physical activity and hapiness was strongest for domestic or vocational physical activity. However, we must be cautious because to Van Kim and Nelson (2013) vigorous physical activity recommendations were less likely to report poor mental health.

The benefits of physical activity on depressive symptoms and perceived stress were examined by Asztalos *et al.* (2009b), Torres *et al*. (2014), and Zhang *et al.* (2015). To Torres *et al*. (2014), walking frequency is a modifiable risk factor for elevated depressive symptoms in African-American women. Asztalos *et al.* (2009b) shared this opinion and invited consideration for differentiated health recommendations for physical health and for mental health in different population subgroups. The latter concluded, as Goodwin (2003), that physical activity ameliorates depressive symptoms among mildly and moderately depressed individuals, most notably among mildly depressed women. These benefits depended on individual's self-management as stated by Forbes *et al.* (2017).

Regarding natural environments, Mitchell (2013) stated that physical activity in different types of environment may promote different kinds of positive psychological response. One of these responses is a decrease of psychological distress (Astell-Burt *et al*., 2013). Indeed, Cohen-Cline *et al.* (2016) asserted that greater access/proximity to green space is associated with lower depression rate, but provide less evidence for effects on stress or anxiety. To Triguero-Mas *et al.* (2015) and Dadvand *et al.* (2016) green spaces were associated with better self-perceived general health. For example, Marselle *et al.* (2015) assured that perceived walk intensity predicted greater positive effect and happiness following an outdoor group walk. However, Ambrey (2016) provided evidence that this synergy is greater in more populated neighbourhoods. Sturm and Cohen (2014) quantified the relationship green space/well-being and stated that a nearby urban park is associated with the same mental health benefits as decreasing local unemployment rates by 2 percentage points. Moreover, Richardson *et al.* (2013) were interested in physical benefits of green space and state that

neighbourhood green space was related to better cardiovascular and a lower probability of being obese. Moreover, to Pasanen *et al.* (2014) the benefit is mainly in the sleep quality.

The question of elderly people was treated by ten of our references. First of all, Benedetti *et al.* (2008), Parker *et al.* (2008), Withall *et al.* (2014) and Steinmo *et al.* (2014) suggested that higher volume of physical activity was related to a favourable mental health profile and reduce/delay the risks of dementia. To Black *et al.* (2015), adult participation in self-selected activities such as leisure-time physical activity and walking were positively related to mental well-being, whereas total levels of free-living physical activity were not. For example, to Buman, *et al*. (2010) replacing 30 minutes/day of sedentary time with equal amounts of low-light or high-light physical activity was associated with better physical health and lower levels of fatigue Kwag *et al.* (2011). The question of adolescents was treated by Ho *et al.* (2015) who affirmed that promoting physical activities that build up resilience could be a promising way to improve adolescent mental health. The question of women was the topic of Griffiths *et al.* (2014) who found that midlife and older women who reported increased physical activity by more than two hours per week demonstrated a reduced risk of later mental ill-health in comparison with those who did not increase physical activity.

However, both mental and physical health are moderately state-dependent (Ohrnberger *et al.*, 2017a, 2017b): better past mental health increased present physical health significantly. Better past physical health had a larger effect on present mental health.

Team sport is equally a component of the relationship of physical activity and mental health, Miller and Hoffman (2009) found that both participation in a team sport and athlete identity were associated with lower depression scores. Rasciute and Downward (2010) added that active travel has a broadly positive effect.

Finally, we conclude our comparison with the impact of physical activity on the subjective well-being. It is a positive effect according to Downward and Rasciute (2011) and Lee and Park (2010) who accessed the evidence of positive “non-health effects” of physical activity on life satisfaction. Downward and Dawson (2016) recommended

active leisure that has a higher value of well-being than active leisure that does meet the guidelines.

The results of the 40 econometrics studies are summarised in the Table A (annex). This table shows that physical activity has different effects on mental health. Although the majority of the papers concluded a positive relationship, there are two papers that found a negative relationship. The main benefits seemed to be a reduction of perceived stress, a delay of the risks of dementia and of future symptoms of mental ill-health. Physical activity also increased subjective well-being and levels of happiness. These last two effects were identified with some features such as green exercise, team sport and low-light and high-light intensity of activity. The walk appears to be the favourite activity to reach these benefits. However, two of our references (Ambrey 2016 and Dadvand *et al.* 2016) showed a negative relationship with mental health. This depends on the environment and intensity: in more populated neighbourhoods, physical activity is negatively associated with psychological distress. Low intensity exercises (recreation) in green space don't improve mental health. Nevertheless, high intensity exercises expose individuals to risk of depression. Finally, there are equally mitigated results. It is the case for three of our references (Black *et al.* 2015, Cohen-Cline *et al.* 2016 and Goodwin 2003). Regular physical activity was associated with a significantly decreased prevalence of current major depression and anxiety disorders, but not with other affective, substance use, or psychotic disorders. A greater access to green space was associated with less depression, but provided less evidence for effects on stress or anxiety. For the elderly, participation in self-selected activities (LTPA and walking) was positively related to mental well-being, whereas total levels of free-living physical activity were not. The mitigated results require further research work.

All these papers have provided solid evidence of a significant relationship between physical activity and mental health. Yet, the causal impact of physical activity on mental health has not been sucessfully tackled in the majority of the paper. Papers cannot identify the causal effect because there are difference sources of endogeneity. Some authors (e.g. Rasciute and Downward, 2010; Lee and Park, 2010; Kuvaja-Kollner *et al.*, 2013) stated the first endogeneity issue is between the health/well-being and physical activity variables. For example, it may well be the case that more healthy

individuals are more able to undertake sports participation, or to engage in active travel, with more happy individuals being more inclined likewise (Rasciute and Downward 2010). The second issue is between the physical activity and respective health and well-being variables. This is the case for the individuals with better physical ability who may have more physical activity or sport participation and be more satisfied with their lives than those with worse physical ability (Lee and Park, 2010). Another example comes from that self-management activities (exercise and relaxation). To Forbes *et al.* (2017), physical activity has the potential to be endogenous if there is an unobserved variable that is correlated with both these inputs and health outputs or there could be unobserved individual characteristics that drive both the extent of self-management activity and health.

However, several solutions are proposed by the authors. Rasciute and Downward (2010) dealt with the endogeneity through reduced form' equations estimating health and well-being on a full set of covariates and using the classical models of investment in health capital. Lee and Park (2010) included control variables for the efficacy of perceived physical ability and confidence of physical expression, while Kuvaja-Kollner *et al.* (2013) used instrumental variables technique because of the endogeneity of the motivation for exercise. Their strategy was firstly to use components in the model for physical exercise as independent variables. Secondly, to explain physical activity with the main components (motivation, labour market, …). Lastly, they implement an instrumental variable model. The instrumented variable, moderate-to-heavy physical exercise, increased the physical component summary (PCS) and the mental component summary (MCS).

On the contrary, Forbes *et al.* (2017) adopted a simultaneous recursive trivariate model that controls for the potential endogeneity of exercise and relaxation and for unobserved heterogeneity between the three equations: one output equation (health) and two input equations (exercise and relaxation). The last solution of our references comes from Zhang *et al.* (2015) who used an ordered switching probability model with binary endogenous physical activity. They estimated several alternative models with such reverse causality, including the ordered probit model for physical activity with

binary endogenous depression as well as a binary probit for physical activity with binary depression treatment.

3.5. **Other systematic reviews**

We also came across a number of systematic reviews for which this study can be compared to. Tomporowski *et al.* (2011), Eime *et al.* (2013), Murray *et al.* (2016), Hallgren *et al.* (2016), Stanton *et al.* (2014), Peluso *et al.* (2005), Rosenbaum (2014), Zschucke *et al.* (2013) studied the relationship between physical activity and mental health while Herrick, C. (2009) add green spaces and exercises to this relationship and discussed the policy implications. Zschucke *et al.* (2013) is the only paper written as an epidemiological article.

All authors find a positive effect of physical activity on mental health and well-being but they differ in their recommendations. For example, Stanton *et al.* (2014) recommended individualised cardiovascular exercises according to preferences of people and their time and financial resources. To Murray *et al.* (2016) golf can be an interesting physical activity while it is yoga and martial arts, to Eime *et al.* (2013) as there exist a lot of benefits of team sport. According to Zschucke *et al*. (2013) and to Peluso *et al.* (2005), all is a question of physical intensity. However, from Hallgren *et al*. (2016) and Vancampfort *et al.* (2017) points of view, none of this is possible without a suitable public intervention.

4. Discussion

The main objective of this paper was to review the existing literature that investigates the relationship between physical activity and mental health. We conduct a rigorous systematic review based on 47 studies and providing an overview, comparing and summarising the main findings of this association. It enabled us to map the key concepts and insights available, summarise the research findings and identify research gaps in the existing literature.

There is a consensus that physical activity is associated with improved mental health. Indeed, results show that:

- Physical activity was effective in reducing depressive symptoms among people with mildly and moderately symptoms.

- Participation in team sports rather than individual activities is associated with better mental health.

- Exercise in green environment: green spaces had a positive impact of mental health. For example, they increase levels of physical activity of individuals living close to these areas.

- The positive association is found regardless of the age. For the elderly, physical activity is related to a favourable mental health profile, reduces/delay the risks of dementia and levels of fatigue are lower. While for the adolescents, physical activities building up resilience is a promising way to improve adolescent mental health.

All these benefits seem to appear with a low to moderate cardiovascular exercises for 30 minutes per session with three sessions per week (Buman, *et al*. 2010). Nevertheless, the type of exercises should be individualised according to preferences and access to resources. It must also be emphasised that physical activity can also be harmful, especially when performed in high intensity which leads to mood variations as anxiety or depression.

The abovementioned evidence, support the claim that physical activity interventions may serve as a cost-effective means to promote physical health with the added benefit of facilitating mental development. However, our paper presents some limitations. The first one coming from the criteria used to decide on the papers that made us exclude a number of them. Secondly, as we highlight above there are some endogeneity issues in this relationship that only some papers try to control for. As a result, this is a threat to external validity in order to make policy recommendation. Thirdly, the definition of intensive physical activity is not clear, as it can be very subjective.

This research showed us some potential gaps in the literature. The most important one is to overcome selection and endogeneity to move to causal estimations. For this reason, exogenous variation needs to be examined in order to solve these issues. For

instance, an exogenous intervention applied in the health system. Overcoming these econometric problems would allow is to do policy recommendation. Other future research could be trying to define better the role of intensity of physical activity on mental health, as there is not enough evidence yet. Overall, further research is certainly needed into the effects exercise on mental health before making general public recommendations.

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Annex

Table A. Risk assessment

	Selection bias	Ecological fallacy	Confounding bias	Reporting bias	Time bias	Measurement error in exposure variable	Measurement error in health outcome	Overall rating
Econometric papers								
Ambrey (2016)	1	1	1	1	3	2	3	2
Astell-Burt et al. (2013)	1	1	1	1	2	2	2	1
Asztalos *et al.* (2009a)	1	1	1	1	2	1	3	2
Asztalos *et al*. (2009b)	1	1	1	1	3	1	2	2
Benedetti *et al* (2008)	2	1	2	2	3	2	2	2
Black *et al.* (2015)	1	1	1	1	2	2	2	1
Buman *et al.* (2010)	2	1	2	1	2	2	3	2
Cohen-Cline *et al.* (2016)	2	1	1	1	2	2	3	2
Dadvand *et al.* (2016)	1	1	1	1	3	2	2	2
Downward and Dawson (2016)	1	1	1	1	3	2	3	2
Downward and Rasciute (2011)	1	1	1	1	2	2	3	2
Forbes *et al.* (2017)	2	1	1	1	3	2	3	2
Goodwin (2003)	1	1	1	1	3	3	1	2
Griffiths *et al.* (2014)	1	1	1	1	2	2	2	1
Hamer *et al.* (2009)	1	1	1	1	3	3	2	2
Ho *et al.* (2015)	2	1	1	1	3	2	2	2
Kwag *et al.* (2011)	2	1	1	1	3	2	2	2
Ku *et al.* (2014)	2	1	1	1	2	2	2	1
Ku *et al.* (2016)	1	1	1	1	2	3	2	2
Kuvaja-Kollner *et al.* (2013)	1	1	1	1	2	2	2	1
Marselle *et al* (2015)	2	1	2	1	2	2	2	1
Miller and Hoffman (2009)	3	1	2	2	3	2	2	2
Mitchell (2013)	1	1	1	1	3	2	2	2
Lee and Park (2010)	2	1	1	1	3	3	3	3
Lordan and Pakrashi (2014)	1	1	1	1	2	2	2	1
Parker *et al.* (2008)	2	1	2	2	3	1	2	2
Pasanen *et al*. (2014)	3	1	1	1	2	2	2	2
Ohrnberger *et al.* (2017a)	1	1	1	1	2	2	2	1
Ohrnberger *et al.* (2017b)	1	1	1	1	2	2	2	1
Rasciute and	1	1	1	1	2	2	3	2

Downward (2010)								
Richards *et al.* (2015)	1	1	1	1	3	2	3	2
Richardson *et al.* (2013)	1	1	1	1	3	2	3	2
Steinmo *et al.* (2014)	2	1	1	1	2	2	2	1
Sturm and Cohen (2014)	2	1	2	2	2	3	2	2
Torres *et al.* (2014)	2	1	2	2	3	3	2	2
Van Kim and Nelson (2013)	3	1	2	2	3	3	2	2
Withall *et al.* (2014)	3	1	1	1	3	1	2	2
Yuenyongchaiwat (2016)	3	1	2	2	3	1	2	2
Zhang *et al.* (2015)	1	1	1	1	3	3	2	2
Tuekpe *et al*. (2006)	3	1	2	2	3	3	2	2
Statistical papers								
Barton *et al* (2005)	3	1	2	2	3	1	2	2
Barton and Pretty (2010)	3	2	2	2	2	2	2	2
Galper *et al.* (2006)	2	1	2	2	3	2	2	2
Harris (2018)	2	1	2	2	3	2	2	2
Lawton *et al.* (2017)	3	1	2	2	3	2	2	2
Marselle *et al*. (2013)	3	1	2	2	3	2	2	2
Pretty *et al.* (2007)	3	1	2	2	3	2	2	2

Source: own construction. Parmar et al. (2016) followed.

Table B: Summary of econometrics references

References	Model	Database	Effect	Findings
Ambrey (2016)	Cluster-specific fixed model	Household, Income and Labour Dynamics in Australia (HILDA) survey 2013	-	Physical activity is negatively associated with psychological distress. This synergy is greater in more populated neighbourhoods
Astell-Burt *et al.* (2013)	Logistic regression model	Australians living in New South Wales (2006–2009).	+	Mental health benefits of greener environs appear contingent upon physical activity
Asztalos *et al.* (2009a)	Logistic regression model	Flemish Policy Research Centre Sport, Physical Activity and Health (2002–2004)	+	Sports participation is the only type of physical activity inversely associated with both stress and distress
Asztalos *et al*. (2009b)	Logistic regression model	Belgian National Health Interview Survey.	+	Physical activity–mental health relationship is always positive, regardless of activity intensity
Benedetti *et al* (2008)	Logistic regression model	Probabilistic sample of elderly people from a	+	Physical activity is able to reduce and/or delay the risks of dementia

		city of Southern Brazil, in 2002.		
Black *et al.* (2015)	Linear regression	United Kingdom Medical Research Council (MRC) National Survey of Health and Development (2006–2011)	+/-	For the elderly, participation in self-selected activities (LTPA and Walking) are positively related to mental well-being, whereas total levels of free-living PA are not
Buman *et al.* (2010)	Mixed-effects regression models	Senior Neighborhood Quality of Life Study of adults aged >65 years in Baltimore, Maryland, and Seattle, Washington (2005-2007).	+	Low-light and high-light physical activity are positively related to physical health
Cohen-Cline *et al.* (2016)	Multilevel model	Community-based University of Washington Twin Registry 2008–2014.	+/-	Greater access to green space is associated with less depression, but provide less evidence for effects on stress or anxiety
Dadvand *et al.* (2016)	Logistic regression model	Health Survey of Barcelona, 2011	-	Better SGH associated with residential surrounding greenness and subjective proximity to green spaces which could be explained in part by mental health status and perceived social support and to less extent, by higher levels of physical activity
Downward and Dawson (2016)	Instrumental variables	Irish Longitudinal Study on Ageing (2009-2011) and European Urban Atlas 2012.	+	Active leisure that is not of a recommended intensity to generate health benefits has a higher value of well-being than active leisure that does meet the guidelines
Downward and Rasciute (2011)	Ordered choice model	Taking Part Survey from 2005, UK	+	Sports participation has a positive affect upon the subjective well-being
Forbes *et al.* (2017)	Logistic regression model	Whole System Informing Self-Management Engagement a trial based in the north-west of England (2009 – 2012)	+	Individuals tailor their self-management activities to their economic constraints
Goodwin (2003)	Logistic regression model	National Comorbidity Survey, US, (1990-1992)	+/-	Regular physical activity is associated with a significantly decreased prevalence of current major depression and anxiety disorders, but not with other affective, substance use, or psychotic disorders
Griffiths *et al.* (2014)	Logistic regression model	Finnish Public Sector Study (FPSS), phase 2 2000-2002 and phase 3 2004-2005 and phase 3-	+	Inverse dose–response relationship between physical activity and future symptoms of mental ill-health

		5, 2008-2009		
Hamer *et al.* (2009)	Logistic regression model	Scottish Health Survey, 1995, 1998, 2003	+	Mental health benefits were observed at a minimal level of at least 20 min/week of any physical activity
Ho *et al.* (2015)	Path model	Students in Grades 7 and 8 (ages 12 to 14) from 12 secondary schools in Hong Kong, China	+	Significant positive association between the PA level and mental well-being
Kwag *et al.* (2011)	Structural equation modeling	Participants were from two counties in a Midwestern state, representing a rural and an urban county.	+	PA predicts lower levels of fatigue among older adults.
Ku *et al.* (2014)	Linear regression	A cross-sectional survey on community-dwelling older adults aged 65 or older in Kaohsiung, Taiwan (2009).	+	Physical activity taken as leisure has greatest potential to enhance the quality of life of older adults
Ku *et al.* (2016)	Linear regression	Nationwide Survey of Health and Living Status of the Elderly conducted by Taiwan Ministry of Health and Welfare (1999-2007)	+	Both LTPA and aspects of LTSB in later life may provide beneficial effects for subsequent SWB
Kuvaja-Kollner *et al.* (2013)	Multiple regression	Dose-Responses to Exercise Training (DR's EXTRA) Study 2005–2006.	+	Motivation and the labour market position are important in determining the cost of physical exercise
Marselle *et al* (2015)	Multilevel model	Participants recruited from a larger Walking for Health (WfH) a national group walk program in England (2011)	+	Perceived restorativeness and perceived walk intensity predicted greater positive affect and happiness following an outdoor group walk
Miller and Hoffman (2009)	Multiple regression	2006 Athletic Involvement Study, undergraduate college students at a Northeastern university (US)	+	Relationship between mental well-being and a larger constellation of health-risk behaviors linked to a "toxic jock" identity
Mitchell (2013)	Logistic regression model	2008 Scottish Health Survey (SHS)	+	Physical activity in natural environments is associated with a reduction in the risk of poor mental health
Lee and Park (2010)	Probit model	Survey data from the Korean Sports Association for the	+	Positive "non-health effects" of physical activity on life satisfaction

		Disabled (2008).		
Lordan and Pakrashi (2014)	Linear regression	Health Survey for England (HSE) 1999, 2002,2003, 2004, 2006 and 2008	+	Lower probability of poor health roughly to the same level with PA (± 30 mins)
Parker *et al.* (2008)	Linear regression	Participants recruited from the local community Wisconsin, US.	+	Higher volume of PA is related to a favorable mental health profile
Pasanen *et al*. (2014)	Structural regression models	Nationwide Outdoor Recreation Demand Inventory (LVVI2), conducted by the Finnish Forest Research Institute (2009)	+	Nature provides an added value to the known benefits of physical activity
Ohrnberger *et al.* (2017a)	Dynamics models	Six waves of data from the English Longitudinal Study of Ageing (ELSA), 2002–2013, UK.	+	Past mental health has stronger effects on present physical health than physical activity or education. Past physical health has stronger effects on present mental health than health investments, income or education
Ohrnberger *et al.* (2017b)	Dynamic model	The English Longitudinal Study of Ageing (ELSA), 2002 to 2012, UK.	+	Past mental (physical) health has a significant direct and indirect impact on physical (mental) health. Physical activity is the largest contributor to the indirect effects
Rasciute and Downward (2010)	Probit model	Taking Part Survey, Department for Culture Media and Sport and conducted by the British Market Research Bureau (2005)	+	Physical activity and active travel have a broadly positive effect on mental health
Richards *et al.* (2015)	Logistic regression model	Eurobarometer 2002	+	Increasing physical activity volume was associated with higher levels of happiness.
Richardson *et al.* (2013)	Multilevel model	New Zealand Health Survey 2006/07	+	Neighbourhood green space was related to better mental health
Steinmo *et al.* (2014)	Latent growth curve	Whitehall II cohort in the UK (1997/99)	+	From midlife to old age, greater physical activity is associated with better mental health and vice versa
Sturm and Cohen (2014)	Multiple regression	Data from a study of capital improvements of neighborhood parks in Los Angeles (2004-2008).	+	Mental health is significantly related to residential distance from parks
Torres *et al.* (2014)	Logistic regression model	National Survey of American Life. The sample was made up of	+	Walking frequency is a modifiable risk factor for elevated depressive symptoms

		community-dwelling African-American		
Van Kim and Nelson (2013)	Logistic regression model	National sample of undergraduate students attending 4-year colleges in the United States done by the Harvard School of Public Health Study of College Health Behaviours in 2004	+	Inverse association between vigorous PA in college and both poor mental health and perceived stress
Withall *et al.* (2014)	Multiple regression	Participants from the Older People and Active Living (OPAL) Project, funded by the National Prevention Research Initiative, Bristol.	+	Improving perceptions of physical health and function may provide an important target for physical activity programmes
Yuenyongchaiwat (2016)	Multiple regression analysis	Participants were overweight adults from Pathumthani, Thailand	+	Walk at least 10,000 steps over a 12-week period improves physical and mood states in sedentary and overweight individuals
Zhang *et al.* (2015)	Probability model	2011 Behavioral Risk Factor Surveillance System (BRFSS), US	+	Physical activity ameliorates depressive symptoms, most notably among women
Tuekpe *et al*. (2006)	Multiple regression analysis	A group of Japanese overseas workers (and spouses) who resided in and around Düsseldorf, Germany, in February 1994.	+	PA is the major lifestyle factor for a good mental health

Table C: Summary of statistical references

References	**Effect**	**Findings**
Barton *et al.* (2005)	+	Both rural and urban pleasant scenes produced a significantly greater positive effect on self-esteem
Barton and Pretty (2010)	+	Green environments improve both self-esteem and mood and the presence of water generated greater effects
Galper *et al.* (2006)	+	Inverse graded dose-response relationship increased with a walk or run of 11–19 miles per week
Harris (2018)	+	An increase in mental well-being is significantly greater for the least active prior to the intervention.
Lawton *et al.* (2017)	+	The main benefit of green exercise is that somatic anxiety is lower for outdoor physical activity.
Marselle *et al*. (2013)	+	Groups walks in specific types of natural environments are associated with greater psychological and emotional well-being
Pretty *et al.* (2007)	+	Green exercise led to a significant improvement in self-esteem and total mood disturbance

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