Journal of Technology in Behavioral Science
https://doi.org/10.1007/s41347-024-00442-6

WAT's up? Exploring the Impact of Wearable Activity Trackers on Physical Activity and Wellbeing: A Systematic Research Review

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Received: 2 February 2024 / Revised: 4 July 2024 / Accepted: 22 September 2024

Abstract

Wearable activity trackers (WATs) can facilitate engagement in physical activity. Yet, there may be an additional psychological impact, which can influence their effectiveness. Therefore, the aim of this systematic review was to assess the impact of wrist-based WATs on physical activity and subsequent psychological wellbeing in healthy adults. The review was carried out using PRISMA guidelines and registered on the Open Science Framework (OSF). An initial search was conducted in December 2022 with a follow-up in October 2023. Databases included PsychInfo, PsycArticles, ScienceDirect, Web of Science and SPORTDiscus. Nine studies were selected for inclusion and reviewed. Most studies comprised white adults with an average age of 21.5 to 49 years. Participants were employed or students with a mostly normal BMI. Changes in self-efficacy for exercise, depressive symptoms, mental health and general wellbeing, quality of life and burnout were evaluated. Half the studies reported a WAT-related increase in physical activity engagement. Four studies assessed self-efficacy for exercise, with half observing an improvement post-intervention. Three studies assessed mental health and depressive symptoms with one observing improvement and two observing no change. The remaining studies included measures of burnout and quality of life, where only burnout scores improved 1-month post-intervention. Although the quality of the studies reviewed was acceptable, only 4 included a suitable control/comparison group. Further, the measurement of psychological wellbeing varied considerably. In sum, the results indicate that the effect of WATs on physical activity and subsequent psychological wellbeing is understudied. Further research is required to fully elucidate these relationships.

Keywords Exercise · Physical activity · Wellbeing · Activity trackers

Introduction

Wearable activity trackers (WATs) have become increasingly popular among the general public over the last few years and are now a go-to lifestyle choice. Indeed, the global activity tracker market is on an upward trajectory, rising from $36.34 billion in 2020 to an estimated $114.36 billion in 2028 (Fortune Business Insights, 2022). One of the main reasons why a person may acquire a WAT is to increase their engagement in physical activity. Being physically active can improve physical health as well as psychological wellbeing in adults (Bauman et al., 2004). Therefore, many wellbeing interventions include some aspect of physical activity engagement (Santos & Miragaia, 2023), and in these interventions, it is common to see the inclusion of activity tracker technology, specifically the use of wearables (Lunney et al., 2016). This is based on evidence suggesting that WATs can facilitate increases in physical activity, which may then lead to improvements in physical health and wellbeing (Brickwood et al., 2019; Nuss et al., 2021). Consequently, it would be pertinent to assess the simultaneous impact of WAT use on both physical activity and psychological wellbeing.

WATs are forms of wearable technology which are worn by the user for the purpose of monitoring and/or influencing the health and wellbeing of the wearer (Wortley et al., 2017). These are distinct from other activity trackers which can take the form of mobile phone and web-based applications or traditional pedometers. The effectiveness of WATs can be explained by their power to act as a motivator. In other words, the WAT serves as a behavioural nudge and reminder to engage in a desired behaviour, in this case, physical activity. As WATs provide users with feedback on what they have accomplished, the rewarding nature of the WAT is consistent

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with the idea of self-determined extrinsic motivation which is reminiscent of Self-Determination Theory (Deci & Ryan, 1985). Within this framework, motivation exists on a continuum from intrinsic motivation (in which the user is fully engaged in an activity through enjoyment), extrinsic motivation (whereby engagement is facilitated due to the presence of reward), and finally amotivation (or the absence of any motivation to engage in the behaviour). The stage of motivation in which a user finds themselves is determined by how well three psychological needs are met: autonomy (choice over behaviour), relatedness (the need for connection with others) and competence (a sense of mastery over the behaviour in question; Ryan & Deci, 2000). Consequently, the WAT, acting as an extrinsic motivator, offers reward for behavioural engagement and moves the user into self-determined extrinsic motivation.

Although there is an appeal in using WATs because of their effectiveness in increasing engagement in physical activity, their psychological impact remains unclear. Therefore, it is important to understand the interplay among WATs, physical activity and psychological wellbeing. We assume that if we exercise more, we feel better. Therefore, if a WAT helps to increase physical activity, *ergo*, it can also improve psychological wellbeing. However, a recent study by Lasikiewicz and Scudds (2023), which explored the effects of a WAT (Fitbit™) on work-related wellbeing and physical activity engagement in full-time working healthy adults, found that the psychological impact of using a WAT was not always positive. In their study, participants were asked to exercise at least once a week for two consecutive and counterbalanced weeks, one while wearing a Fitbit™ and one without. The results indicated that participants experienced *greater* temporal demand when wearing a Fitbit™ and being unable to exercise. In addition, they seemed to experience frustration when exercising and *not* wearing the Fitbit™. Surprisingly, participants exercised *less* when wearing a Fitbit™. These unexpected results highlight the need for more research into the consequences of WAT use on the interplay between physical activity and psychological wellbeing in a healthy adult population.

Based on Lasikiewicz and Scudds (2023), a better understanding of the impact of WATs on psychological wellbeing, when used to increase physical activity, in healthy adults is needed. "Wellbeing" is a term often used to describe aspects of mental health and wellness. Usually, this focusses on positive psychological states and can incorporate aspects of mental health, self-esteem and self-efficacy. However, defining wellbeing in a research context can be problematic due to the many different facets it can include (Simons & Baldwin, 2021). In broad terms, wellbeing centres on a state of equilibrium or balance that can be affected by life events or challenges (Dodge et al., 2012). For the purposes of the current review, emphasis will be placed on aspects of mental health, namely wellbeing, mood, positive and negative affect, stress, anxiety and depression, self-efficacy and self-esteem and rumination.

Despite the recent findings which highlight the potential negative consequences of wearing a WAT on wellbeing, and the increasing popularity of WAT use, the psychological impact of WAT use on wellbeing is very unclear. Lasikiewicz and Scudds (2023) have indicated the potential for a complex relationship between WAT use, exercise and psychological wellbeing in healthy adults. Therefore, the aim of this systematic review is to evaluate the impact of a wrist-based WAT on physical activity engagement and psychological wellbeing in healthy adults. In sum, we planned to review studies in which the population of interest was healthy adults, the intervention consisted of wearing a wrist-based WAT whose impacts were compared across timepoints and/or against a control group and the outcomes measured related to both physical activity and psychological wellbeing as defined above. In other words, the psychological outcomes most frequently assessed were identified and discussed in relation to increases in physical activity.

Method

The motivation for this review derived from Lasikiewicz and Scudds (2023), who concluded that the impact of wearable activity trackers (WATs) on both engagement in physical activity and subsequent psychological wellbeing, is more complex than expected. This review was performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Page et al., 2021) and was registered on the Open Science Framework (OSF), under associated project number osf.io/362n8. Searches of electronic databases were initially carried out on 14th December 2022, with a follow-up search conducted on 25th October 2023, to evaluate the impact of a wrist-based WAT on physical activity engagement and psychological wellbeing in healthy adults. It was imperative that studies included *both* the assessment of physical activity engagement together with psychological wellbeing.

The following databases were searched: PsycARTICLES, PsycINFO, ScienceDirect, SPORTDiscus and Web of Science. Searches were limited to academic journals. To ensure that all relevant studies were captured, a range search of terms were used. For example, the following key words were used to identify studies which utilised "activity trackers": "fitness tracker", "activity tracker", "wearable activity tracker", "wearable activity monitor", "smart watch", "wearable technology" using the 'OR' operator. The same search strategy was applied to "physical activity" and "wellbeing". For a full list of search terms and strings, see Table 1. Due to the difference in the limits to the number of Boolean

Table 1 List of search terms (*permits variation in spelling)

	Search strings
1	(“fitness tracker” OR “activity tracker” OR “wearable activity tracker” OR “wearable activity monitor” OR “smart watch” OR “wearable technology”) AND (“physical activity” OR exercise) AND adults AND “mental health”
2	(“fitness tracker” OR “activity tracker” OR “wearable activity tracker” OR “wearable activity monitor” OR “smart watch” OR “wearable technology”) AND (“physical activity” OR exercise) AND adults AND (wellbeing OR well*)
3	(“fitness tracker” OR “activity tracker” OR “wearable activity tracker” OR “wearable activity monitor” OR “smart watch” OR “wearable technology”) AND (“physical activity” OR exercise) AND adults AND (mood OR “positive affect” OR “negative affect”)
4	(“fitness tracker” OR “activity tracker” OR “wearable activity tracker” OR “wearable activity monitor” OR “smart watch” OR “wearable technology”) AND (“physical activity” OR exercise) AND adults AND (depression OR anxiety OR self-esteem OR self-efficacy OR stress OR rumination)

connectors in ScienceDirect, the search strings were modified to prioritise the search towards the wearable activity trackers with the additional search terms incorporated in the advanced search options.

According to the PICO strategy (acronym for P, population/patients; I, intervention/exposure; C, comparison/control; O, outcome), the study population comprised healthy adults and the intervention represented by the inclusion of a wearable activity tracker (WAT) as part of a physical activity intervention. Comparisons were made either (i) before and after the implementation of a WAT-based intervention or (ii) across different forms of intervention, for example, WAT versus no-WAT. All aspects related to psychological wellbeing were considered as outcomes, in addition to change in physical activity. Therefore, studies that assessed changes in mental health, wellbeing, mood, positive or negative affect, depression, anxiety, self-esteem, self-efficacy, stress and rumination were considered.

Eligibility Criteria

Review papers or studies published in any language other than English were excluded. Studies were included or excluded in this review using the following criteria which were determined *a priori*:

Device

This review *only* included papers which assessed the use of a wrist-based wearable activity tracker (WAT). In addition to being wrist-based, the devices were required to have some kind of display providing feedback, either in the form of lights (e.g. to signal that the user has completed a certain number of steps) or a digital display. Only devices from 2009 onwards were included (coinciding with the launch of the first wrist-based Fitbit^{TM} device (Comstock, 2015)). Studies which solely assessed the use of mobile phone applications or monitors which are worn in locations other than the wrist (e.g. chest straps) were excluded unless they were included as a comparison to a wrist-based device.

Participants

The target sample included healthy adults aged between 18 and 65 years old. No restrictions on the sex of participants or prior activity level were imposed. However, studies that sampled only from clinical populations and those with pre-existing psychological or physical health conditions were excluded.

Study Design

The review aimed to explore studies which quantitatively assessed the effect of wearing a wrist-based wearable activity tracker (WAT) on engagement in physical activity, and subsequent psychological wellbeing. The focus of the current review was to explore the specific relationship between wearing a WAT for physical activity and the impact of this on psychological wellbeing. Therefore, it was a requirement that studies included a WAT and assessed both physical activity and wellbeing when wearing the WAT and, ideally, when not. Crossover randomised controlled trials (RCTs) were also included. No restrictions on the length of intervention were imposed. Qualitative studies were excluded unless they included a substantial quantitative element in a mixed methods approach.

It was important that studies presented an analysis of physical activity and psychological wellbeing as outcomes either (i) before and after the implementation of a WAT-based intervention or (ii) comparing physical activity and psychological outcomes across different forms of intervention, for example, WAT versus no-WAT.

Outcomes

Studies were considered if they included (i) an assessment of physical activity *and* (ii) at least one form of assessment of psychological wellbeing. The following facets of wellbeing were included: mental health, wellbeing, mood, positive and negative affect, stress, anxiety and depression, self-efficacy and self-esteem and rumination. There was no restriction on the measurement tools used. Further, no restrictions on the type of exercise or method of assessing the quantity of exercise were imposed. The reported psychological outcomes were used to group the studies in the review, and, consequently, six categories of wellbeing were created: (i) mental health and general wellbeing, (ii) self-efficacy for physical activity, (iii) quality of life, (iv) burnout, (v) depressive symptoms and (vi) vigour.

Selection Process

The screening procedure, including initial searches, was performed by both authors. Duplicate records were excluded. Qualitative studies (with no quantitative element) and review articles were excluded. Studies were selected by title and abstract, according to the inclusion/exclusion criteria. Eligible studies were selected, read fully and discussed to reach consensus on whether they met the inclusion criteria.

Figure 1 details the stages of study selection and the number of studies excluded at each stage after the initial searches were performed, following PRISMA guidelines. The search strategy yielded a total of 904 citations after removal of duplicates. Of these, 855 were excluded as they did not meet the inclusion criteria. From the remaining 49 studies, some studies were excluded due to a lack of inclusion of measures of psychological wellbeing (n=11) or measurement of physical activity (n=4). A further six papers were excluded because they either (i) did not include a WAT or (ii) the WAT included was not wrist-based (for example, Fitbit™ Zip). Additionally, five papers were excluded because the samples were recruited from a clinical population, reported psychological or physical health conditions or fell outside the target age range. Further, those studies which were cross-sectional or adopted a cluster design (i.e. there was no comparison) were excluded (n=15).

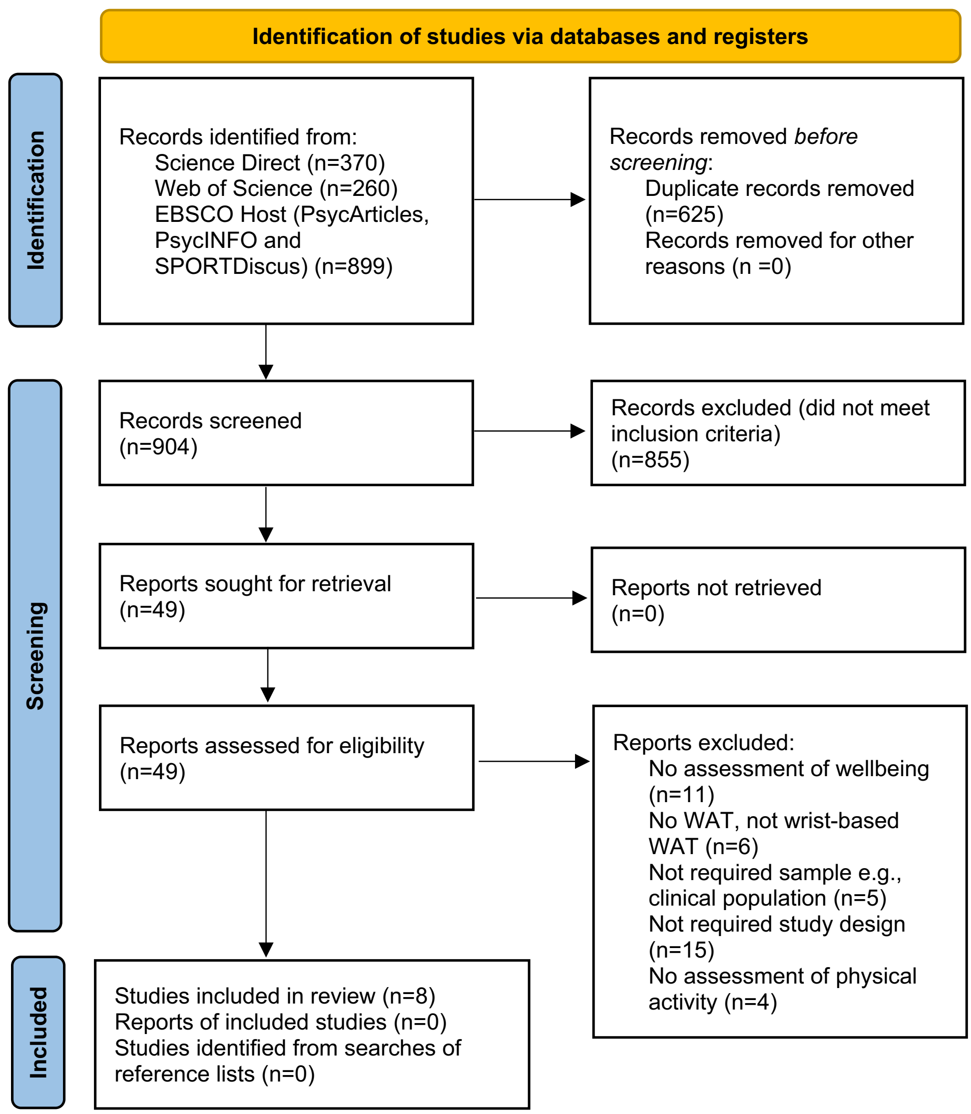

Fig. 1 PRISMA flow diagram for study selection process (14th December 2022). From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. https://doi.org/10.1136/bmj.n71

Following exclusion of studies that did not meet the inclusion criteria and review articles, eight studies remained after the initial search conducted on 14th December 2022. Additional search strategies included hand searches of reference lists of review articles identified, but this did not yield any further citations. Figure 2 details the stages of study selection, and the number of studies excluded at each stage including after the follow-up search was performed on 25th October 2023 which resulted in the addition of one study.

Data Collection Process

Both authors performed data extraction from each of the studies included in the review. This included data on sample size and characteristics, device used, study design and duration, measures of psychological wellbeing and physical activity and main findings. Table 2 summarises the main characteristics of each study. Sample characteristics (including sample size, sex, age, ethnicity, BMI and employment status (where available)) were included. The nature of the intervention is documented together with the device, study design, duration of intervention and measures used to assess psychological and physical (physical activity) outcomes. Where data was not available, "not stated" was included in the tabulation of studies.

Quality Assessment

An 18-item quality assessment tool, based on a tool previously used by Lasikiewicz et al. (2014) and adapted from a similar tool used in Hoyland et al. (2009)was used. This tool assessed key elements of study aims and design, sample, use of WATs and appropriateness of use, measures of compliance, analysis and outcomes, including risk of bias. All criteria were equally weighted and a score of 1 was given if the criterion was satisfied. Each study was rated for quality

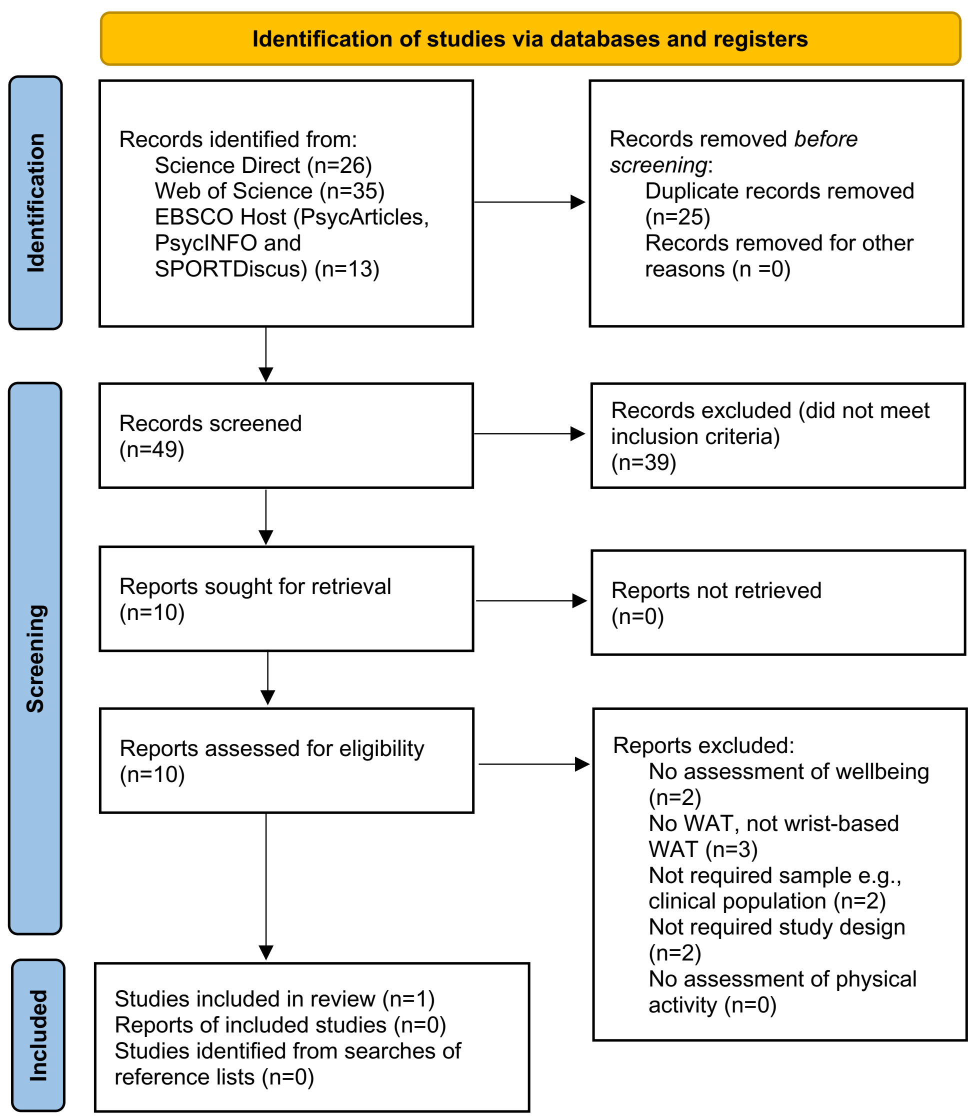

Fig. 2 PRISMA flow diagram for study selection process (updated search on 25th October 2023). From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. https://doi.org/10.1136/bmj.n71

Table 2 Characteristics of the studies included in the review with physical activity and psychological wellbeing outcomes post-intervention (n=9)

Reference	QA	Sample	*N*	Device	Study design	Psychological outcomes	Physical activity outcomes	Duration	Findings
Busch et al. (2020)	14	*Age:* ET mean age = 25.56 ± 4.54 years; ENT mean age = 25.78 ± 4.78 years; Control mean age = 22.73 ± 4.32 years *Sex:* Overall 77.66% female; ET 72% female; ENT 80% female; Control 81% female *Ethnicity:* Not stated *BMI:* ET 22.33 ± 3.11 kg/m^2; ENT 22.14 ± 2.86 kg/m^2; Control 21.74 ± 3.18 kg/m^2 *Employment status:* Not stated *Other:* Healthy adults; self-reported exercise of <4hrs p/w; fitness app novices (no more than 2 weeks of use)	152 ET = 50 ENT = 50 Control = 52	Fitbit Flex 2	RCT: ET Group = Fitbit Flex 2 plus target of 10k steps per day; ENT = Fitbit Flex 2 but no target; C= Control group (self-observation of physical activity)	*Mental Health and General Wellbeing:* WHO-5	10K step count set as target for ET group but data not reported	6 weeks	No effects of fitness app usage and implementation of an external step target were found on psychological wellbeing. Data on physical activity engagement not reported

Table 2 (continued)

Reference	QA	Sample	*N*	Device	Study design	Psychological outcomes	Physical activity outcomes	Duration	Findings
Centi et al. (2019)	8	*Age:* Overall mean age 48.96 ± 9.54 years *Sex:* 30% male *Ethnicity:* 70% white *BMI:* Mean BMI = 32.48 ± 4.59kg/m^2 *Employment status:* 50% employed *Other*: Overweight and obese adults (BMI or 25kg/m^2 or greater	30	Choice of Fitbit Charge, Flex or Zip	Non-randomised pilot study with one week baseline followed by 8 weeks with personal step goal	*Depressive symptoms*: PHQ-8 *Quality of Life:* PROMIS Global 10 (using Global Physical Health and Global Mental Health scores)	Unique, personal daily step goal set at 10% above the number of steps at baseline	9 weeks	No change in depressive symptoms or quality of life (mental health) but improvement in quality of life (physical health) in those who engaged more Less than 50% of the sample achieved their step goal

Table 2 (continued)

Reference	QA	Sample	*N*	Device	Study design	Psychological outcomes	Physical activity outcomes	Duration	Findings
Lee et al. (2019)	14	*Age:* Experimental Mean age = 37.68 ± 9.31years; Control Mean age = 34.42 ± 4.16 years *Sex:* Not stated *Ethnicity:* Not stated *BMI:* Not stated *Employment status:* 100% employed *Other:* Healthy workers in two manufacturing companies	79 Experimental = 41 Control = 38	Fitbit Charge HR	Quasi-experimental study used a pre- and post-test non-equivalent control group design	*Mental Health and General Wellbeing:* Wellness Index for Workers *Self-Efficacy for Exercise:* Self-efficacy for PA (*tool not specified* but based on 8-item scale developed by Kang & Gu, 2006)	Daily step count Physical activity subscale of the HPLP II	5 working days for 12 weeks	Significant interaction shows no significant increase in step count for experimental group but significantly decreased in control group Significant interaction shows a significant increase in physical activity behaviour for experimental group but no change in control group Significant interaction shows a significant increase in wellness for experimental group but no change in control group Significant interaction shows an increase in physical activity self-efficacy for experimental group but no change in control group

Table 2 (continued)

Reference	QA	Sample	*N*	Device	Study design	Psychological outcomes	Physical activity outcomes	Duration	Findings
Lennefer et al. (2020)	15	*Age:* Mean age = 43.01 ± 12.72 years *Sex:* 45.7% female *Ethnicity:* Not stated *BMI:* Mean BMI = 27.21 ± 4.74 kg/m^2 *Employment status:* 100% employed *Other:* Workplace intervention targeting employees who were physically inactive	116 Intervention = 59 Control = 57	Garmin Vivofit 3	RCT: Intervention = WAT plus support (e.g., online coach, gamification) Wait list control Follow up assessment at 1, 3 months and 1 year for intervention group only	*Burnout:* German version of the Shirom–Melamed Burnout Measure (physical fatigue, cognitive weariness, emotional exhaustion) *Vigour:* German Version of the Utrecht Work Engagement Scale	Modified version of the Godin Leisure-Time Exercise Questionnaires Scores used to calculate a total score of weekly MVPA	3 weeks	Intervention successfully increased MVPA compared to control No significant difference in burnout post-intervention but significant long-term reduction at 1 month but not maintained at 3 months or 1 year No significant impact on vigour
Lopes et al. (2017)	10	*Age:* Experimental mean age=31.6 ± 11.5 years; Control mean age=26.3 ± 6.9 years *Sex:* 65% male *Ethnicity:* Not stated *BMI:* Experimental mean BMI = 24.8 ± 3.7 kg/m^2; Control mean BMI = 24.6 ± 4.1kg/m^2 *Employment status:* 100% employed *Other:* Workplace intervention; employees (office workers)	20 Experimental = 10 Control = 10	Oregon Scientific™ Model Ssmart Dynamo PE 128, China	Intervention study: GE (experimental) = WAT for 12 weeks GC (control) = no WAT	*Quality of life:* SF-36	IPAQ (mins)	12 weeks	No effect of intervention on physical activity or quality of life

Table 2 (continued)

Reference	QA	Sample	*N*	Device	Study design	Psychological outcomes	Physical activity outcomes	Duration	Findings
Middelweerd et al. (2020)	15	*Age:* Mean age = 23.4 ± 3.0 years *Sex:* 79.8% female *Ethnicity:* Not stated *BMI:* Overall mean BMI = 22.8 ± 3.4kg/m^2 *Employment status:* 69.2% students *Other:* Young adults aged 18–30 years	92 Active2Gether Full = 24 Active2Gether Light = 23 Fitbit = 45	Fitbit 1 **Note**: Participants were also asked to wear ActiGraph wGT3X+/wGT3XBT to collect baseline and postintervention activity data	Quasi-experimental Active2Gether-Full condition (tailored coaching messages, self-monitoring, and social comparison) Active2Gether-Light condition (self-monitoring and social comparison) Fitbit-only control condition (self-monitoring)	*Self-Efficacy for Exercise:* Self-efficacy for PA (*tool not specified* but based on 13-item questionnaire developed by Sallis et al., 2017)	ActiGraph wGT3X+/wGT3XBT	12 weeks	No effect of intervention on physical activity or self-efficacy for PA
Pope et al. (2019)	16	*Age:* Mean age = 21.5 ± 3.4 years; Experimental mean age = 21.2 ± 4.0 years; Comparison mean age = 21.8 ± 2.8 years *Sex:* Experimental = 78.9% female; Comparison = 68.4% female *Ethnicity:* 71.1% white *BMI:* Experimental mean BMI = 24.9 ± 3.3kg/m^2; Comparison mean BMI = 23.8 ± 4.6 kg/m^2 *Employment status:* 100% student *Other:* College students	38 Experimental group = 19 Comparison group = 19	Polar M400 Smartwatch	Randomised pilot trial. Experimental group = WAT and Facebook group (SCT- and SDT-based PA and nutritious eating health education tips twice weekly) Comparison group = Facebook group only	*Self-Efficacy for Exercise:* Self-efficacy for PA (*tool not specified* but comprised 5 items based on Carlson et al., 2012; Brief Psychosocial Scales)	MVPA, LPA and SB per day (mins)	12 weeks	Both groups increased both physical activity and self-efficacy. No impact of WAT observed. Only descriptive statistics reported

Table 2 (continued)

Reference	QA	Sample	*N*	Device	Study design	Psychological outcomes	Physical activity outcomes	Duration	Findings
Seo et al. (2020)	11	*Age:* Not stated *Sex:* Overall 60% male; Individual-based = 50% male; Connected group = 60% male *Ethnicity:* Not stated *BMI:* Individual mean BMI = 23.58 ± 3.62kg/m^2 ; Connected mean BMI = 24.52 ± 3.31 kg/m^2 *Employment status:* Not stated *Other:* N/A	40 Individual-based = 20 Connected group = 20	Jawbone UP24 **Note**: participants completed baseline assessment using Sense-Wear Mini armband for 7 days	Randomised to an individual-based or connected group Individual-based = WAT plus self-tracking Connected group = WAT plus engagement with friends/family (social connectivity)	*Self-Efficacy for Exercise:* Self-efficacy for PA (*tool not specified*)	Step count	8 weeks	Step count increased for connected group No change in self-efficacy

Table 2 (continued)

Reference	QA	Sample	*N*	Device	Study design	Psychological outcomes	Physical activity outcomes	Duration	Findings
Zahrt et al. (2023)	16	*Age:* Overall median = 40 years; Accurate median = 42 years; Deflated = 41.5 years; Inflated = 39 years; Meta = 39 years *Sex:* Overall 73% female; Accurate = 76% female; Deflated = 75% female; Inflated = 65% female; Meta = 76% female *Ethnicity:* 43% white *BMI:* Not stated *Employment status:* 46% employed *Other:* Community dwelling adults	162 Accurate step = 41 Deflated step = 40 Inflated step = 40 Accurate plus Meta-Mindset Intervention = 41	Apple Watch Series 1	Criteria-based randomisations 1 = Accurate step count only 2= Manipulated step feedback (deflated) 3 = Manipulated step feedback (inflated) 4 = Accurate step count plus meta-mindset intervention	*Mental Health and General Wellbeing:* Mental health: PROMIS-29 Self-esteem: Single item assessment Affective processes: Affect Valuation Index	Step count plus self-reported activity	5 weeks	Results from accurate step count condition only: Improvement in mental health scores Marginal increase in self-esteem (not significant) No change in either positive or negative affective processes No change in step count or self-reported physical activity for the accurate step group

Note: only aspects of studies relevant to review are included

RCT randomised controlled trial *HPLP II* Health-Promoting Lifestyle Profile II, *IPAQ* International Physical Activity Questionnaire, *LPA* Light Physical Activity, *MVPA* Moderate to Vigorous Physical Activity, *PANAS* Positive and Negative Affect Scale, *PHQ-8* Patient Health Questionnaire, *PROMIS Global 10* Patient-Reported Outcomes Measurement Information System Global 10, *PROMIS 29* Patient-Reported Outcomes Measurement Information System 29, *SB* Sedentary Behaviours, *SF-36* Medical Outcomes Survey Short Form (36) Health Survey, *WHO-5* World Health Organisation - Five Wellbeing Index using the pre-defined assessment criteria (Appendix 1) by both authors independently. Discrepancies in ratings were discussed to reach consensus. Inter-rater reliability (IRR) was assessed using a two-way mixed, absolute agreement average measures intra-class correlation coefficient (ICC). The resulting ICC indicated a high level of agreement (ICC = .956). Quality assessment (QA) ratings appear in Table 2. An *a priori* decision was made to not exclude studies based on low scores, as their contribution was still worthy of consideration by the scientific community.

Results

The goal of this review was to assess the impact of the use of a WAT on physical activity engagement *and* psychological wellbeing. To understand the context in which the reviewed research was carried out, demographic data were collated. However, such data were not always reported. From the available information, it was apparent that most studies used samples comprising white males and females with an average age ranging from 21.5 to 49 years old. Participants were typically either employed or students and reported a BMI mostly within a normal range, although one study (Centi et al., 2019) specifically targeted an overweight/obese sample.

As wellbeing is a multidimensional construct, categorisation was achieved based on the focus of the tools used in the papers considered. Consequently, six categories of psychological wellbeing were created and used to group the studies: (i) mental health and general wellbeing (ii) self-efficacy for physical activity, (iii) quality of life, (iv) burnout, (v) depressive symptoms and (vi) vigour. Three studies assessed mental health and general wellbeing, four papers assessed self-efficacy for physical activity, two studies assessed quality of life, one study assessed burnout, one study assessed depressive symptoms, and one study assessed vigour. Three of the studies assessed more than one measure of wellbeing.

Quality Assessment

Each paper in the final sample was subject to a quality assessment (QA) to measure the standard of methodological vigour (Table 2). Quality scores ranged from 8 to 16 (M=13.00, SD=3.20) with six out of the nine studies scoring between 11 and 16 out of a possible 18. The assessment indicated an acceptable standard of quality with 89% of studies achieving a QA score of more than 50%. However, no study fulfilled all the criteria specified to achieve the maximum quality score.

Only two out of the nine studies were randomised controlled trials (RCTs). Of the remaining seven studies, only two included a control group without access to a WAT. Four studies included a control or comparison group, but in these instances, participants had access to a WAT, with the comparison made based on the amount of social support or exercise target. Finally, one study did not include a control or comparison group and was based on a pre-post assessment only.

Physical Activity Engagement

Of the nine studies, four reported positive increases in physical activity following the intervention (Lee et al., 2019; Lennefer et al., 2020; Pope et al., 2019 and Seo et al., 2020). However, in Seo et al. (2020), the improvement was only observed for those in the connected group (WAT plus social connectivity) suggesting that the WAT alone was insufficient. Three studies reported that the intervention was not successful in increasing physical activity (Lopes et al., 2017; Middelweerd et al., 2020 and Zahrt et al., 2023). Of the remaining two studies, one did not report the results for physical activity engagement (Busch et al., 2020), and in the other study, the authors only commented on the observation that less than 50% of the sample achieved their target step goal and did not report accompanying statistics.

Wellbeing

Mental Health and General Wellbeing

Three studies assessed the impact of WATs on mental health and general wellbeing. Of the three studies, one utilised a Fitbit^{TM} Flex, one a Fitbit^{TM} Charge HR and in one study an Apple Watch. In their RCT, Busch et al. (2020) measured wellbeing via the WHO-5 questionnaire (German version), Lee et al. (2019) used the wellness for workers measure, and Zahrt et al. (2023) used the PROMIS-29, the Affect Valuation Index and a single item assessment for self-esteem. Busch et al.'s (2020) results failed to show that using a WAT increased psychological wellbeing, even when the WAT was accompanied by an external step target. Lee et al.'s (2019) results revealed an increase in wellness scores after a 12-week mobile wellness intervention, but only for those who had been provided with a WAT and received brief counselling with targeted text messages. However, their assessment was only made post-intervention with no comparison to baseline. Zahrt et al. (2023) recorded an improvement in mental health scores but only for participants who were given an accurate step count provided by the WAT. No changes in self-esteem and positive and negative affect were noted.

Self-Efficacy for Exercise

Four studies assessed the impact of using a WAT on self-reported self-efficacy for exercise. Of the four studies, two utilised a WAT in the form of a Fitbit™, one used a Jawbone, and one used a Polar M400 smartwatch. Each of the four studies utilised a different measure for self-efficacy for exercise. In all instances, the tools used were based on previous measures from other studies. In each paper, the authors provided little information on the contents of these measures making comparison difficult. Two of the four studies did not find an improvement in self-efficacy for exercise following the intervention (Middelweerd et al., 2020; Seo et al., 2020). The remaining two studies observed better self-efficacy for exercise post-intervention. However, Lee et al. (2019) only compared experimental and control groups post-intervention. Further, Pope et al. (2019) observed an improvement in self-efficacy for exercise in both experimental and comparison groups, therefore, unrelated to the use of a WAT.

Quality of Life (Mental Health)

Two studies assessed the impact of using a WAT on quality of life, with specific focus on mental health. Of the two studies, one gave participants a choice of a Fitbit™ Charge, Flex or Zip (Centi et al., 2019), while the other utilised the Oregon Scientific™ Model Ssmart Dynamo (Lopes et al., 2017). Quality of life was assessed in one study using the PROMIS Global-10 (Global Mental Health scores) and the SF-36 in the other. Neither study reported an improvement in quality of life.

Burnout

Only one study assessed the impact of using a WAT on self-reported burnout. In a randomised controlled trial (RCT), Lennefer et al. (2020) explored the impact of a workplace intervention on work-related wellbeing (burnout and vigour) utilising a WAT (Garmin Vivofit 3) with an online coach versus wait-list control. Burnout was assessed using the German version of the Shirom–Melamed Burnout Measure (Shirom et al., 2005). No improvement in burnout was recorded at the end of the 3-week intervention, but there was a reduction in burnout 1-month post-intervention. However, this was not maintained at three months and 1-year post-intervention.

Depressive Symptoms

Only one study assessed the impact of using a WAT (choice of Fitbit™ Charge, Flex or Zip) on self-reported depressive symptoms. Centi et al. (2019) utilised the Patient Health Questionnaire (Kroenke et al., 2009) to assess depressive symptoms at enrolment and close-out of a 9-week WAT-based intervention with daily goal setting. No improvement in depressive symptoms was observed.

Vigour

Only one study assessed the impact of using a WAT on self-reported vigour. Lennefer et al. (2020) utilised a three-item subscale of the German Version of the Utrecht Work Engagement Scale (Sautier et al., 2015; Schaufeli et al., 2006). Vigour was assessed in conjunction with burnout in an assessment of work-related wellbeing. No improvements in vigour were reported as a result of the RCT.

Interplay Between WAT Use and Physical Activity on Psychological Wellbeing

Given that the aim of this systematic review was to evaluate the impact of a wrist-based WAT on physical activity engagement and psychological wellbeing in healthy adults, it was of interest to see if any of the papers included in the review directly assessed the interplay between physical activity engagement as a result of a WAT *on* psychological wellbeing. In other words, did those who wore a WAT *and* engaged in physical activity report greater psychological wellbeing. However, the only paper reviewed here that made such an assessment was Centi et al. (2019), where the only significant change observed was for Global Physical Health, where scores were higher in those who engaged more with a daily step goal. The remainder of the papers did not use engagement in physical activity as a grouping variable, meaning it was not possible to assess the interplay between the impact of wearing a WAT and subsequent level of physical activity on psychological wellbeing.

Discussion

The aim of this paper was to provide a systematic review and quality assessment of studies that have evaluated the impact of a wrist-based wearable activity tracker (WAT) on physical activity engagement in conjunction with psychological wellbeing in healthy adults. A review of nine studies suggests that the evidence of the effectiveness of WATs for physical activity and subsequent psychological wellbeing is extremely limited. Much of the literature on the impact of WATs focuses on physical activity and rarely considers psychological outcomes. Either the WAT is used to record physical activity or as a motivator to increase physical activity. In both instances, the psychological impact of a WAT is unknown.

Considering the high percentage of adults who use these devices, it is surprising that the body of research exploring this issue is so limited. Indeed, the results of the current review have cemented the conclusion that very little research has been done to fully explore the effect of wearing a WAT on physical activity and subsequent psychological wellbeing, with only nine studies meeting our inclusion criteria. However, even in these nine studies, the assessment of psychological wellbeing was extremely limited. For example, many (44%) focussed on self-efficacy, but specifically self-efficacy for exercise. Of these, only half observed a positive effect. Studies assessing the more typical facets of wellbeing, such as mental health and depressive symptoms, only accounted for 33% of the studies included in the review. Again, findings were mixed with only one study reporting a positive effect and two observing no change in wellbeing. The remainder of studies included measures of wellbeing assessed in the form of burnout and quality of life (including vigour). Of these, only burnout scores were found to improve, but only 1-month post-intervention with no change at any other time point. Interestingly, only one study in the review (Centi et al, 2019) directly assessed the interplay between physical activity engagement as a result of a WAT on psychological wellbeing. Participants who engaged more with the WAT showed improvement but only in terms of perceived physical health.

As discussed in Lasikiewicz and Scudds (2023), the use of a WAT for physical activity can have both positive and negative effects in terms of work-related wellbeing. For example, their users reported greater frustration when exercising and not wearing the Fitbit™ and greater demand when wearing the Fitbit™ but being unable to exercise. Further, some studies have suggested links between the use of fitness trackers and negative psychological outcomes such as eating disorder symptomology (Simpson & Mazzeo, 2017). This indicates that the impact of a WAT extends beyond its potential to increase physical activity. Consequently, the psychological impact of a WAT needs to be further explored. Given that the current review only yielded nine papers, there could be a problem of non-reporting/under-reporting in studies which assessed the psychological impact of WAT use (i.e. there is the potential for publication bias). Further, there was insufficient consistency in study designs to permit a meta-analysis. Thus, it was not possible to fully assess risk of bias in missing results. However, a more likely reason is that many researchers did not consider the psychological impact as part of their research aims in the first place.

Of the nine studies reviewed, the suggestion that a WAT can increase physical activity was not always supported. Indeed, a positive effect of wearing a WAT on subsequent physical activity engagement was observed in only half of the studies examined. This contrasts with prior research findings suggesting that a WAT can successfully increase physical activity (for example, Brickwood et al., 2019). Interestingly, although many studies cite the power of these devices as important tools for physical activity, many did not utilise this in their design nor did they comprehensively report the results of using the WAT, for example, with step counts or minutes exercised. This is somewhat surprising considering the significant uptake of these devices with a particular goal of increasing physical activity behaviour (Laranjo et al., 2021). This is further compounded by the observation that the measurement of physical activity was often based on self-report measures rather than using the WAT as it is intended (Prince et al., 2008).

Although there was a range of age groups, incorporating both males and females with a normal to overweight BMI, the samples included in the review lacked diversity as they were predominantly white. Further, participants tended to be either full-time workers or students. Taken together, this may limit the generalisability of the findings. However, this is difficult to assess given that not all papers provided sufficient demographic data.

Given the mixed findings from the studies in this review, it is apparent that there are limitations that future research should address. Broadly speaking, these centre on the utilisation of a WAT in the study of physical activity, the effective measurement of psychological wellbeing and appropriate research designs to enable the evaluation of these. It became apparent that the WATs were not the focus of the research in the studies reviewed and were often only included as a mere measurement tool. Consequently, many studies did not comprise a control condition characterised by the absence of a WAT. This means that our assessment of the effectiveness of a WAT is extremely limited. When comparisons were made, this was in terms of additional support, i.e. WAT alone compared with WAT with social support (for example, Lennefer et al., 2020), but without the inclusion of a no-WAT group. In most studies, comparisons were made between treatment groups and only assessed wellbeing and physical activity post-intervention (Lee et al., 2019), meaning that there was no baseline comparison. This is problematic as it means the effectiveness of a WAT for both physical activity and wellbeing cannot be fully determined. In other words, the design of these studies lacked the sophistication needed to fully assess the impact a WAT can have. Indeed, future research should explore the *behaviour* of wearing a WAT and the subsequent impact this can have on its effectiveness.

It is estimated that 12 devices were utilised across the nine studies reviewed. It is difficult to provide an exact number as in one study, participants were given the choice of a device from a range of options (Centi et al., 2019). Consequently, there is great heterogeneity in the use of a WAT which also makes comparisons difficult. This highlights a lack of standardisation among the tools used which further amplifies any differences between WATs in terms of functionality (for example, the presence of a display, the potential for reminders and feedback). Additionally, some studies used a WAT as part of their intervention but did not utilise its capabilities to record physical activity. Specifically, one study (Middelweerd et al., 2020) used a different device during the intervention to the one used to measure physical activity before and after the intervention. Thus, the activity tracker was not used to collect data for analysis. Presumably, this was due to the WAT being deemed inadequate to accurately record physical activity for data collection. Another study based their analyses on the use of self-report measures for physical activity (Lennefer et al., 2020) rather than using the WAT. This may be problematic as it could also modify the perceived validity and reliability of the WAT in the eyes of the participants and, consequently, reduce its effectiveness. However, this is purely speculative, and further research is needed to elucidate this possibility. Furthermore, surprisingly in some studies, physical activity was recorded but not analysed.

Reminiscent of the variation of the type of WATs used, there was also considerable variation in the measurement of wellbeing which, again, makes comparisons between studies difficult. Researchers should strive to include validated instruments to ensure consistency of measurement. This would elevate the quality of the results obtained and permit more meaningful comparisons to be made between studies. Further, in the current review, the term "wellbeing" should be applied loosely, as almost half of the studies were limited to the assessment of self-efficacy for exercise. Indeed, very few studies explored the more common facets of wellbeing, such as depression and anxiety. Regardless of these limitations, it is important to note that only three of the nine studies reviewed found a significant effect on wellbeing post-intervention.

One explanation for the variation in measures of psychological wellbeing may be the lack of consensus on what defines the construct. Wellbeing has a long history of debate relating to how it is operationalised. The presence of competing definitions suggests that wellbeing includes many different facets (Simons & Baldwin, 2021). This becomes problematic when wellbeing is assessed in a research context. Hence, researchers can use a multitude of different tools dependent on their definition of wellbeing. This can range from broad to very focussed assessments which often only target specific dimensions such as self-efficacy (Cooke et al., 2016). Consequently, more consideration should be devoted to the selection and inclusion of the most appropriate tools to ensure accuracy and consistency of the reporting of outcomes.

Of those studies which observed an improvement in wellbeing, additional elements to the interventions may hold some explanatory power. Of these, the degree with which participants engage with the WAT may be important. Centi et al. (2019) found that when participants engaged more with the WAT, it was more effective. Prior studies have observed this when exploring the effect of WATs on physical activity (Laranjo et al., 2021), but in this context, its influence may also extend to psychological wellbeing. This suggests that a WAT alone is insufficient to improve physical activity and wellbeing and that some form of additional support or encouragement is necessary. Lee et al. (2019) utilised a WAT in conjunction with a mobile wellness intervention which included goal setting, brief counselling and motivational text messaging, compared to a control group that only received a WAT. Since only the experimental group showed improvements in physical activity and wellbeing, they concluded that additional support was needed for a WAT to influence wellbeing, and the device alone was not enough. Other studies have explored the effectiveness of additional tools such as gamification (Cho et al., 2021) and social support (Zhu et al., 2017). This further supports Self Determination Theory (Deci & Ryan, 1985) as a mechanism to explain the effectiveness of WATs. Specifically, this contributes to the fulfilment of the psychological need of relatedness, in other words, the need for connection with others. Thus, in addition to the WAT acting as a source of reward, it may also enhance user connectedness. Again, encouraging self-determined extrinsic motivation (Ryan & Deci, 2000). Based on this, some consideration of engagement is needed for future studies aiming to explore the impact of WATs on physical activity in conjunction with psychological wellbeing.

Recommendations for Future Research

Our review of the studies presented here highlights the need for more research into the impact of WATs on physical activity in conjunction with psychological wellbeing. Although the quality of studies included was generally acceptable, there was noted variation in methodology which centred on research design. Gaps in terms of key demographic information also meant that it was difficult to assess the diversity of the samples included. Firstly, researchers need to carefully consider how a WAT will be utilised in the research. Emerging research indicates that a WAT can yield both a positive and negative impact on physical activity and psychological wellbeing (Lasikiewicz & Scudds, 2023). Therefore, researchers should be mindful of this and carefully define the role a WAT will play in the study design. To accurately assess the power of a WAT, it must be integral to the design of the study. An important observation arising from this review is the impact of the degree of interaction with the WAT on its effectiveness. This is something that researchers should also consider and potentially control for. Most studies reviewed here did not include a suitable control or comparison group without WAT, nor did they adopt a pre-post design with appropriate baseline measurements. This would permit more accurate assessment of the effectiveness of a WAT on physical activity and subsequent psychological wellbeing.

As well as the role of the WAT, studies should also consider how physical activity and psychological wellbeing are assessed. Greater consistency in measurement would permit more useful comparisons of outcomes leading to better knowledge and understanding of the effectiveness of a WAT.

Conclusions

The aim of this systematic review was to examine studies that have evaluated the impact of a wrist-based wearable activity tracker (WAT) on both physical activity engagement and psychological wellbeing in healthy adults. Most studies comprised white males and females with an average age ranging from 21.5 to 49 years old, who were either employed or students and who reported a BMI mostly within the normal range. The review demonstrates that only a few studies have assessed the combined impact of a WAT on both physical activity and psychological wellbeing, and, of these, there is considerable heterogeneity across the nine reviewed studies in terms of devices used, measures utilised and study designs. Summarising the outcomes, it appears that there was little improvement in psychological wellbeing following participation in a physical activity intervention. The findings highlight the need for further research in this area and for key methodological issues to be addressed. Further, as a growing body of research suggests that the psychological impact of a WAT is not always positive, more research is therefore needed to elucidate this possibility.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s41347-024-00442-6.

Author Contribution All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by both Dr Annie Scudds and Dr Nicola Lasikiewicz. The first draft was written by both authors, and both authors commented on previous versions of the manuscript. Both authors read and approved the final manuscript.

Data Availability All data supporting the findings of this study are available within the paper and its Supplementary Information.

Declarations

Ethical Approval This review was conducted in line with the principles of the British Psychological Society (BPS). Approval was granted by the Ethics Committee of University of Chester, School of Psychology (Date 16th February 2023/No. NLAS160223).

Consent to Participate Not applicable

Consent for Publication Not applicable

Competing Interests The authors declare no competing interests.

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