

Systematic review of tracking-based technology for patients with claudication

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Abstract

Introduction: Peripheral artery disease (PAD) typically presents with claudication. Although supervised exercise therapy is recommended, many hospitals do not have a program and therefore patients are unable to receive optimal therapy. Tracking-based technology (TBT), including activity monitors and mhealth applications, have stimulated the expansion into PAD management. This systematic review evaluates the effectiveness of TBT for claudication based on walking performance, perceived walking impairment, and quality of life (QoL). **Methods:** A multidatabase search was undertaken using the terms PAD OR intermittent claudication AND wearable devices OR mobile health applications. This systematic review was conducted according to PRISMA guidelines. **Results:** A literature search identified 586 studies, of which 18 were eligible for inclusion. This totaled 1055 patients, with 15 randomized controlled trials and three cohort studies. Patients in the TBT group showed improvements in all walking ability parameters (including 6-minute walking distance, claudication onset time, maximum walking time, maximum walking distance, and claudication distance), QoL, and in the self-reported walking impairment questionnaires. **Conclusion:** There is evidence for supporting the introduction of TBT into the management of PAD as TBT improves walking performance, functional status, and QoL in patients with PAD. However, further information regarding adherence and compliance rates, as well as long-term outcomes, are imperative in assessing the effectiveness of TBT due to limited existing studies. **PROSPERO Registration No.: CRD42022307731.**

Keywords

exercise therapy, mobile phone application, peripheral artery disease (PAD), smartwatch, tracking-based technology

Introduction

Peripheral artery disease (PAD) affects approximately 236.62 million people worldwide.¹ Its prevalence increases steeply with age, rising from approximately 5% in the age group 60–69 years and more than 20% in those aged over 80.² The main presenting symptom is claudication, which can progress to chronic limb-threatening ischemia.^{3–5} Supervised exercise therapy (SET) is recommended as the first-line treatment for claudication^{9–11} as exercising can reduce the risk of cardiovascular (CV) events⁶ and improve endothelial function^{7,8} and functional performance.^{3–5}

The efficacy of SET to improve walking distances, functional status, and quality of life (QoL) has already been established,^{12,13} including its benefits compared to home-based exercise therapy (HBET) and walking advice.¹⁴ A network meta-analysis¹⁵ showed that SET and HBET improved daily physical activity levels. However, SET is an underutilized tool due to low availability, uptake, adherence,^{16,17} and funding.¹⁸ A

2021 survey revealed that only 48% of vascular units have access to SET in the UK, with only 22% meeting the NICE guidelines and a 25% patient uptake rate. In a recent US study, only 1.3% of those diagnosed with PAD were enrolled to SET and only 5.1% successfully completed the program.¹⁶ Patient-specific barriers include noncompliance (affected by travel arrangements, inconvenience, and cost), lack of motivation, and medical co-morbidities.^{13,17,19}

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Currently, app-based therapies are being used to treat and monitor other medical conditions such as cardiovascular disease (CVD); a meta-analysis of 12 RCTs²⁰ showed that mobile health (mhealth) applications used for management for chronic CVD were associated with lower rates of hospitalizations in heart failure patients and increased medication adherence in patients with heart failure, hypertension, and ischemic heart disease. Another systematic review²¹ showed that multifunctional mhealth apps have improved asthma control and lung function, promoting QoL.

HBET can be an effective alternative to SET, with adequate guidance and follow up.²² HBET involves motivational phone calls, in-person meetings, and remote monitoring, all of which can improve patient acceptability.^{13,23,24} The added provision of self-monitoring allows positive behavioral changes including regular physical activity and increased adherence. Owing to the increasing usage of smartphones and activity-tracking devices, the opportunity to incorporate these devices in the conservative management of PAD has been expanding.¹³ A 2018 Belgium²⁵ study revealed 87% of 99 patients with PAD reported the need for an exercise program, with 67% showing interest in tele-coaching. Therefore, given the increased interest in wearable technology in patients with PAD,^{26–43} this systematic review aims to evaluate the effectiveness of tracking-based technology (TBT) to help improve walking performance and QoL in patients with PAD.

Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines.⁴⁴

All available studies that used TBT to monitor patients with PAD were included. Studies must have reported both baseline and follow-up results. Randomized controlled trials, prospective studies (including cohort), and cross-over studies were included. The comparative groups were standard walking advice or patients with access to SET only (no access to tracking-based technology). Abstracts that were identified but had no corresponding publication were included in the results if data were available for the measured outcomes.

The exclusion criteria consisted of studies that use the TBT only as part of their pre and postintervention assessment. Papers not translated into English were excluded.

Search strategy

The initial search was conducted in April 2022 and a revised search was undertaken in September 2024. Four electronic databases (Embase, MEDLINE, Scopus, and CINAHL) were searched with no time limits. ClinicalTrials.gov was also searched and authors were contacted regarding the progress of ongoing trials. Conference presentations and abstracts were sourced and included if they were eligible.

The search strategy included a combination of MeSH terms involving the condition of interest (e.g., intermittent claudication/ OR peripheral arterial disease/) and the intervention (e.g., wearable devices/ OR mobile health application/). The local health librarian was also consulted about the search strategy (Appendix 1). The project was registered with PROSPERO (Registration No.: CRD42022307731).

Selection process and data collection

Studies were extracted based on the search strategy and the screening process was carried out independently by two reviewers (PS and EM). Irrelevant and duplicate studies were removed. Any disagreements were resolved via discussion and, if a consensus could not be reached, a third senior reviewer was consulted to resolve matters and verify the consequent decision (PWS).

The data were extracted from the finalized studies by the two reviewers independently (PS and IS). Data were extracted to include measures of walking performance, QoL, and adherence. The outcomes of finalized studies were imported into Reference Manager.

Outcomes and data synthesis

The primary outcome was to observe changes in walking performance. Systematic reporting was undertaken to compare the pre and postintervention mean differences in walking performances: 6-minute walk test (6MWT),^{26–32,40–43} maximum walking distance (MWD),^{27,36,37,39,42,43} maximum walking time (MWT),^{26,33–35,41} claudication onset time (COT),^{26,33–35} and claudication distance (CD).^{27,36,37,40,42,43}

The secondary outcomes were changes in the Walking Impairment Questionnaire (WIQ)^{26–28,34,35,37,39,42} (measured and reported in percentages or a scale from 1 to 100) and changes in QoL (measured using validated patient questionnaires). The QoL tools used were the PAD-related QoL questionnaire,²⁹ Vascular QoL (VascuQoL),^{36,39,41–43} the Medical Outcomes Study 36-item Short Form Health Survey (SF-36),^{28,31,34,35,37,40,42,43} and the EuroQol 5-Dimension health status questionnaire (EQ-5D).^{27,43}

A meta-analysis could not be conducted due to study heterogeneity.

Results

Following a literature search, 586 studies were identified, with 501 remaining after duplicate removals. A further 456 were removed following title and abstract review. After full-text review, 27 were excluded, leaving 18 studies that met the inclusion criteria^{38,39} (Figure 1), including one conference abstract with no full-text available. Characteristics of the included studies are described in Table S1.

The 18 studies included one feasibility study,³² two cohort studies,^{38,39} six pilot studies,^{27,29,31,35,36,40} and nine RCTs.^{26,28,30,33,34,37,41–43} Study locations included 10 in the

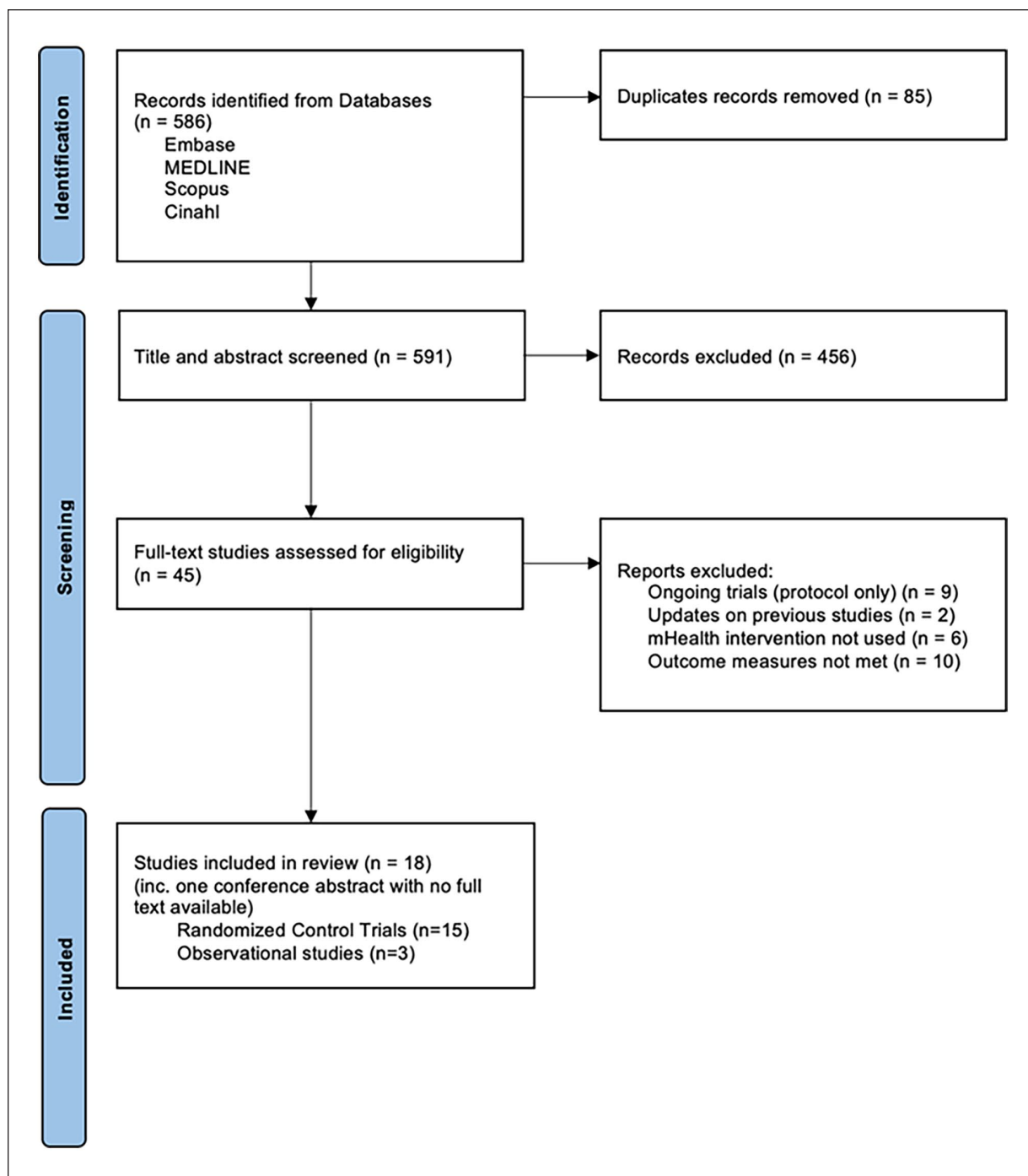


Figure 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flowchart.

United States,^{26,28,30–35,38,42} four in the UK,^{27,36,41,43} and one each in Germany²⁹, Belgium³⁹, Austria,⁴⁰ and the Netherlands.³⁷

Study population

The study size ranged from seven³² to 252,³⁷ with the mean age mostly above 65.^{26–28,30,31,33,34,36–38,41,43} All studies included participants clinically diagnosed with PAD: 16 studies included

symptomatic intermittent claudication,^{26,27,29,31–39,40–43} one study included asymptomatic³⁰ (sedentary patients with an ankle-brachial index < 0.9), and one study included both symptomatic and asymptomatic²⁸ (ABI < 0.9 at rest or 20% drop after exertion, or laboratory and radiographic evidence of PAD or previous revascularization). One study's population³⁵ did, however, include patients previously treated with endovascular therapy along with symptomatic claudication, and another study had a veteran population.³⁸

Study interventions

Sixteen studies applied TBT in HBET^{26–32,34,36–43} and two studies incorporated TBT with SET.^{33,35} Out of the two, one³⁵ started with SET and then progressed to TBT HBET and the other³³ applied the TBT interventions alongside SET classes. For control arms, patients in three studies received a book or brochure,^{27,33,37} one study provided bimonthly videos,³⁰ one provided a light-resistant band program,²⁶ one provided the activity monitor but prevented participants from viewing the data,³¹ and two studies did not report on the care.^{32,36} Two RCTs^{26,34} also included SET for a separate group comparator, which we considered in the systematic review.

Study outcomes

All primary outcome measures and study results are summarized in Table S2 with the available data. All studies objectively measured walking performance: seven studies used 6MWT only,^{28–32,40,41} six studies used a treadmill test,^{33–37,39} and five studies used both.^{26–28,42,43} Five^{26,33–35,41} studies assessed COT, four^{26,33–35} of which used the Gardner graded treadmill test. MWT^{26,33–35,41} was measured by five studies and four^{26,33–35} used the Gardner graded treadmill test. MWD^{27,36,37,39,42,43} was reported by six studies, with five^{27,37,39,42,43} using the Gardner graded treadmill test, and one³⁶ using a constant load treadmill test. Six studies assessed CD.^{27,36,37,40,42,43} One study³⁸ reported on changes in daily walking activity measured in steps/day as its primary outcome.

Eight studies^{26–28,34,35,37,39,42} measured the self-reported PAD-specific WIQ (Table 1). QoL (Table 2) was assessed by 12 studies^{26,27,29,31,35–38,40–43} with varying subjective indicators, with some studies^{42,43} using multiple forms to measure QoL. A PAD-related QoL questionnaire²⁹ was used by one study, eight studies used the SF-36,^{26,31,34,35,37,40,42,43} five studies used VasuQoL,^{36,39,41–43} and two studies used EQ-5D.^{27,43}

Risk of bias assessment

The quality of the RCT studies was analyzed using the Cochrane risk-of-bias tool.⁴⁵

The risk-of-bias summary graph (Figure 2) and assessment of individual studies (Figure 3) suggests most of the RCT studies were of low risk for multiple categories.

One study³² could not be assessed as it was a conference abstract with no full text availability. Nine studies^{26–29,34,35,41–43} out of the 14 RCTs had a low-risk rating for selection bias in both random sequencing and allocation concealment. Eleven studies^{26,29,30,31,33,34,36,37,41–43} had a high risk for performance bias with an additional three^{27,28,35} unsure ratings. Attrition bias and reporting bias were both at low risk for most of the studies. Table S3 assesses the quality of the observation pilot studies^{39,40} and prospective study³⁸ using the Joanna Briggs

Institute (JBI) Critical Appraisal Checklist for case series.⁴⁶ All three studies scored moderately high, with six criteria scoring 3/3 (100%). The weakest scoring criterion was completeness of the inclusion of participants.

Systematic review

Walking performance

Six-minute walking test. A total of 11 studies^{26–32,40–43} reported 6MWT results, totaling 918 patients, including one observational study.⁴⁰ Seven^{26,27,29–32,41} out of the 10 (excluding the observational study) showed significant improvement in 6MWT results in those undertaking TBT compared to the control group. Out of the 11 studies, eight^{26,29–32,40–42} studies demonstrated a significant improvement in 6MWT from baseline to the end of the program in the TBT group, with improvements ranging from 22.3 to 117 meters (including the observational pilot study⁴⁰). However, the study with one of the largest populations ($n = 200$)²⁸ identified no significant improvement when comparing the TBT and control group ($p = 0.31$). One study²⁶ ($n = 180$) had an additional SET group, wherein the TBT group performed significantly better than the SET group ($p < 0.05$) (Table S2).

Maximum walking time. MWT was reported by five studies,^{26,33–35,41} totaling 408 patients. Three^{26,33,34} out of the five determined significant results at follow up compared to baseline, improvements ranging from 110 to 227.6 seconds. All three studies showed significant improvements compared to the control group. When comparing TBT versus SET, one of the two studies^{26,34} revealed TBT performed significantly better than the SET group ($p < 0.05$).³⁴

Maximum walking distance. MWD was reported by five studies,^{27,36,37,42,43} totaling 415 patients. Three studies^{27,36,37} showed significant improvements in the TBT group compared to the control group. Only two studies^{37,42} found a significant improvement (340 m³⁷ and 230 m⁴²) from baseline to the end of the program in the TBT group. However, Normahani et al.³⁶ established the TBT group performed significantly better at only 3 months and 6 months compared to baseline, as at 12 months the results plateaued. The same study showed TBT had a significant benefit at a longer term of 6 and 12 months when compared to the control group (82 m vs –5 m; $p = 0.009$).

One observational cohort study³⁹ reported on MWD at baseline and 4 weeks. There was a mean progression of 58 m (SD 97) from baseline, which was statistically significant ($p = 0.03$).

Claudication onset time. A total of five studies analyzed COT results,^{26,33–35,41} totaling 407 patients. All studies demonstrated a significant difference in the TBT group compared to the

Table 1. Functional status results (Walking Impairment Questionnaire).

Study	Outcome measures (WIQ score) ^a	Intervention group		Control group		p-value	Supervised exercise therapy group (if applicable)		Follow-up assessment
		Baseline	Follow up	Baseline	Follow up		Baseline	Follow up	
Tew 2015 ²⁷	Distance	58.0 (28.9)	70.5 (26.7)	29.8 (20.8)	28.9 (21.9)	< 0.05 ^b			6 weeks
	Speed	53.1 (27.2)	61.8 (20.3)	36.3 (13.7)	32.7 (21.0)	< 0.05 ^b			
	Stair climbing	58.0 (28.9)	70.5 (26.7)	29.8 (20.8)	28.9 (21.9)	< 0.05 ^b			
McDermott 2018 ²⁸	Distance	38.0 (29.4)	52.2 (33.5) ^c	37.7 (27.1)	46.1 (30.0)	0.20			9 months
	Speed	36.7 (19.3)	41.3 (26.4)	40.0 (24.4)	43.4 (24.4)	0.69			
	Stair climbing	49.2 (27.1)	52.2 (32.4)	47.4 (27.6)	50.5 (29.4)	0.97			
Gardner 2011 ³⁴	Distance	32 (29)	42 (33) ^c	43 (34)	44 (31)	> 0.05	25 (26)	38 (31) ^c	12 weeks
	Speed	30 (22)	41 (22) ^c	39 (25)	44 (20)	> 0.05	25 (26)	38 (31) ^c	> 0.05
	Stair climbing	38 (26)	48 (27) ^c	47 (32)	50 (29)	> 0.05	32 (32)	44 (34) ^c	> 0.05
Mays 2015 ³⁵ Mean (SE)	Distance	40.4 (10.4)	60.3 (4.4)	51.8 (10.4)	44.5 (4.4)	< 0.001 ^b			14 weeks
	Speed	43.1 (7.2)	59.7 (5.1)	44.7 (7.2)	37.3 (5.1)	0.006 ^b			
	Stair climbing	43.2 (9.3)	61.8 (10.1)	50.9 (9.3)	51.9 (10.1)	> 0.05			
Nicolai 2010 ³⁷	Distance	0.34 (0.25)	0.68 (0.27) ^c	0.36 (0.22)	0.57 (0.30) ^c	0.007 ^b			12 months
	Speed	0.45 (0.22)	0.58 (0.22) ^c	0.43 (0.20)	0.51 (0.22) ^c	0.005 ^b			
	Stair climbing	0.61 (0.27)	0.76 (0.24) ^c	0.58 (0.27)	0.69 (0.28) ^c	0.085			
Cornelis 2021 ³⁹	Distance	0.45 (0.24)	0.63 (0.27)	N/A	N/A	0.013 ^b			4 weeks
	Speed	0.60 (0.21)	0.63 (0.21)	N/A	N/A	0.528			
	Stair climbing	0.77 (IQR 0.27)	0.80 (IQR 0.32)	N/A	N/A	0.552			
Silva 2023 ⁴²	Distance	32.1 (27.3)	67.6 (33.2) ^c	25.3 (26.1)	70.4 (30.7) ^c	0.533			3 months
		32.1 (27.3)	70.8 (35.0) ^c	25.3 (26.1)	70.1 (36.7) ^c	0.940			6 months
	Speed	20.4 (14.2)	38.8 (18.7) ^c	21.3 (13.1)	38.6 (18.0) ^c	0.903			3 months
		20.4 (14.2)	39.8 (27.6) ^c	21.3 (13.1)	41.7 (24.1) ^c	0.251			6 months
	Stair climbing	38.2 (30.2)	57.8 (36.8) ^c	42.9 (36.0)	58.1 (35.9) ^c	0.705			3 months
		38.2 (30.2)	64.6 (37.8) ^c	42.9 (36.0)	77.8 (29.7) ^c	0.197			6 months

Values are mean (SD) or median (IQR) unless otherwise noted.

^aWalking Impairment Questionnaire (WIQ) scoring system ranges from 1 to 100, with 100 being the best possible score.^bSignificant results compared to control.^cSignificant results compared to baseline.Gardner et al.²⁶ and Waddell et al.⁴³ excluded from table due to lack of WIQ data.

Table 2. Quality of life results.

Study	Outcome measure	Intervention group		Control group		Supervised exercise therapy group			Follow-up assessment
		Baseline	Follow up	Baseline	Follow up	p-value	Baseline	Follow up	
Tew 2015 ²⁷	EQ-5D	0.7 (0.2)	0.8 (0.1)	0.5 (0.2)	0.6 (0.2)	> 0.05			6 weeks
McDermott 2018 ²⁸	SF-36	35.8 (9.4)	36.5 (10.8)	36.9 (9.0)	39.0 (9.6)	0.24			9 months
Fukaya 2021 ³¹	SF-36	36.2 (2.9)	50.17 (2.4)	38.6 (2.5)	42.2 (2.2)		TBT with financial incentives 41.2 (2.1)	52.37 (2.4)	3 months
Gardner 2011 ³⁴	SF-36	40 (22)	48 (23) ^a	55 (19)	54 (18)	> 0.05	37 (17)	46 (21) ^a	12 weeks
Mays 2015 ³⁵	SF-36	42.3 (2.8)	25.2 (2.0)	38.9 (2.8)	40.7 (2.0)	> 0.05			14 weeks
Normahani 2018 ³⁶	VascuQoL	4.7 (3.9–5.2)	5.4 (5.2–5.7) ^a	4.5 (2.8–5.0)	3.48 (2.4–5.2)	0.004 ^a			3 months
Nicolai 2010 ³⁷	SF-36	34.6 (7.1)	5.6 (5.1–5.8) ^a	35.2 (8.1)	4.7 (3.0–5.5)	0.031 ^a			6 months
			5.8 (5.1–6.0) ^a		3.3 (2.6–4.2)	0.065			12 months
			40.4 (8.4) ^a		37.7 (8.8) ^a	0.02 ^b			12 months
Cornelis 2021 ³⁹	VascuQoL	5.14 (0.87)	5.50 (0.91)	N/A	N/A	0.009 ^a			4 weeks
Bearne 2022 ⁴¹	VascuQoL	13.3 (3.5)	14.8 (3.8) ^a	13.9 (3.1)	14.6 ± 3.5	0.17			3 months
		13.3 (3.5)	15.2 (3.9) ^a	13.9 (3.1)	14.6 (3.9)	0.33			6 months
Silva 2023 ⁴²	VascuQoL	15 (2.9)	17.4 (2.7) ^a	16.4 (3.1)	17.4 (2.8)	0.961			3 months
		15 (2.9)	19.0 (4.1) ^a	16.4 (3.1)	19.5 (3.2) ^a	0.799			6 months
		2.8 (0.9)	3.2 (0.7) ^a	2.9 (0.8)	3.2 (0.8)	0.531			3 months
SF-36 Physical	SF-36	2.8 (0.9)	3.3 (0.9) ^a	2.9 (0.8)	3.2 (0.8) ^a	0.587			6 months
		3.9 (0.9)	4.2 (0.8) ^a	3.9 (1.0)	4.1 (0.7)	0.156			3 months
		3.9 (0.9)	4.1 (0.9)	3.9 (1.0)	4.3 (0.8)	0.770			6 months

Values are mean (SD) unless otherwise noted.
^aSignificant results compared to baseline.
^bSignificant results compared to control.
Prenner et al.⁴⁰ and Waddell et al.⁴³ excluded from table due to lack of quality of life data.
EQ-5D, EuroQol 5-Dimension health status questionnaire; SF-36, Medical Outcomes Study 36-item Short Form Health Survey; VasculQoL, Vascular QoL; TBT, tracking-based technology.

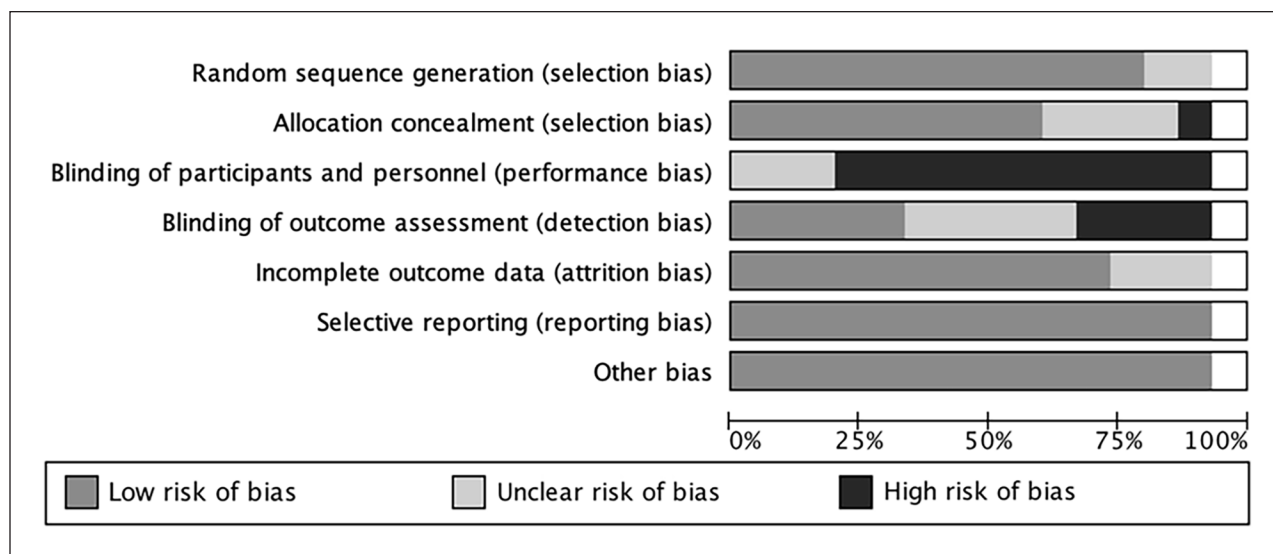


Figure 2. Risk of bias summary graph.

control group. Four^{26,33,34,41} out of the five studies evidenced a significant improvement to their baseline, with improvements ranging from 52.9 to 204.6 seconds. Two^{26,34} of these studies also compared TBT against SET, finding no significant difference between the two groups.

Claudication distance. Seven studies,^{27,36,37,39,40,42,43} including both observational pilot studies,^{39,40} reported on CD, totaling 454 patients. Five^{36,37,39,40,42} out of the seven revealed significant differences from baseline in the TBT group, with improvements ranging from 70 to 350 meters. Only three studies^{27,36,37} showed significant differences compared to the control group, with Normahani et al.³⁶ also displaying significant improvements at 6 (63 m vs 10 m; $p = 0.02$) and 12 (38 m vs 11 m; $p = 0.011$) months compared to the control group.

Functional status

The self-reported validated WIQ has been used by eight studies,^{26–28,34,35,37,39,42} totaling 892 patients (Table 1). Three^{26,27,34} out of the eight reported a significant difference between the TBT group and control group in all three categories. One study³⁴ compared TBT with SET, concluding no significant difference in all categories.

Six^{26,27,34,35,37,42} studies reported significant WIQ distance results when comparing the TBT group and control group. Four studies^{28,34,37,39} showed significant improvements in the TBT group compared to their baselines, with improvements ranging from 10 to 34.

Six studies^{26,27,34,35,37,42} reported significant WIQ speed results in the TBT group compared to the control group. Two^{36,37} demonstrated significant improvements from baseline in the TBT group, with improvements ranging from 16.6 to 18.

Three studies^{26,27,42} reported significant WIQ stair-climbing ability scores compared to the control group and a further two studies^{34,37} noted a significant improvement from baseline in the TBT group, with improvements ranging from 10 to 15.

Quality of life

QoL was reported by 13 studies, using validated questionnaires^{26,27,29,31,34–37,39,40–43} (Table 2). Nine studies^{28,31,34–37,40,42,43} reported on the mean Physical Summary score for the self-reported SF-36, totaling 796 patients. Only one study³⁷ found a significant difference in the TBT group when compared to the control group. Three studies^{34,37,42} observed a significant increase compared to baseline. One observational study⁴⁰ did not provide a mean Physical Summary score, but reported a significant difference in the physical function category ($+13.15\%$, $p < 0.05$).

Five studies^{36,39,41–43} reported QoL using the VasuQoL questionnaire. Only Normahani et al.³⁶ reported significant improvements in the TBT group, compared to the control arm, at 3 months ($p = 0.004$) and 6 months ($p = 0.031$), but this trend plateaued at 12 months ($p = 0.065$). Four^{36,39,41,42} out of the five studies, including Cornelis et al.³⁹ (observational study) identified a significant improvement in the VasuQoL questionnaire from baseline.

Two studies^{27,43} also reported on QoL using EQ-5D; however, no statistically significant differences were reached.

Paldán et al.²⁹ reported on QoL using the self-reported PAD-related QoL questionnaire and significant changes were noted in the TBT group, with patients reporting a less intense subjective symptom perception and a reduction in limitations in physical functioning.

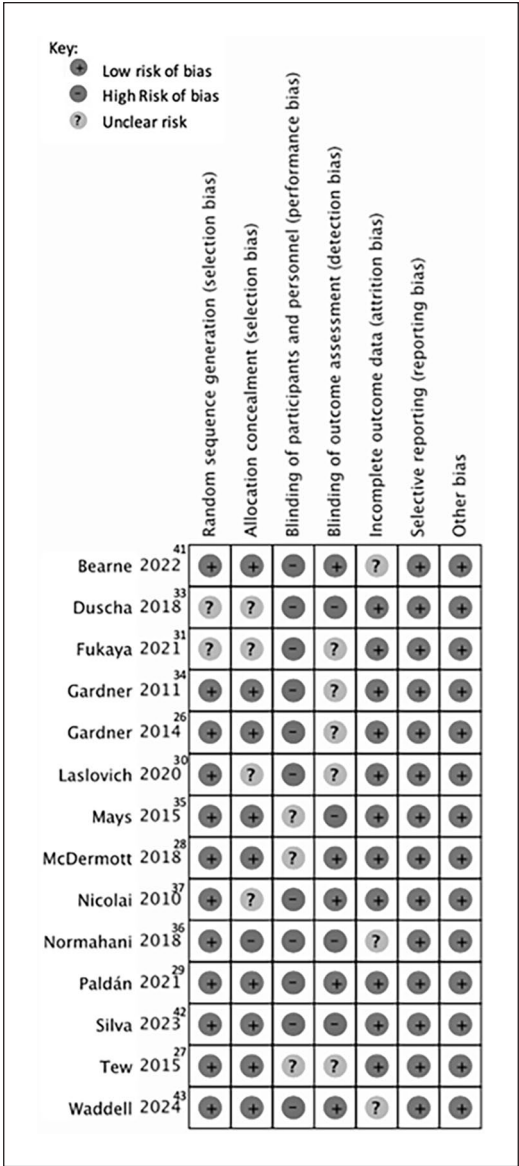


Figure 3. Risk of bias of individual studies.

Discussion

This systematic review of 18 studies has identified TBT as showing significant benefits in terms of walking distance, speed, and time compared to controls. 6MWT, COT, and MWT were increased in the majority of studies compared to the control group and from baseline, as was QoL. In addition, when analyzing the results from the 6MWT, TBT was equivalent or superior to SET.²⁹ Therefore, to counteract the low participation and adherence rates of SET classes, this review provides good evidence to support the usage of TBT at home.

A smaller systematic review and meta-analysis by Kim et al.⁴⁷ evaluated the effectiveness of mhealth-based exercise interventions for patients with PAD and reached a similar consensus. Chan et al.⁴⁸ also evaluated the efficacy of

wearable activity monitors identifying benefits of TBT on walking performance, cardiovascular metrics, and QoL. Evidence from this systematic review and others^{47–49} therefore highlights TBT as a valid alternative (or support) to SET as it can overcome some of the barriers that prevent patients taking part in SET classes, such as travel, convenience, time, and cost.

The introduction of activity monitors and behavioral change techniques in structured HBET has already been recommended in the US PAD guidelines.⁵⁴ With many countries adopting hub and spoke models for their vascular service, or travelling great distances to their vascular center, providing face-to-face SET is challenging. Utilizing TBT can circumvent these issues and allow patients to exercise in their own time and at their own convenience; it also enables healthcare professionals to monitor adherence and formulate personalized walking exercise prescriptions based on participant data. Implementing these technologies can also be undertaken alongside other behavior change techniques, such as motivational interviewing, and help to implement the US PAD and UK NICE guidelines for first-line treatment.

One of the next areas to study is the optimum delivery of these programs. NICE recommend a SET class for 2 hours per week for a period of 3 months. A dosing regimen using an mhealth model is likely to be different to this, utilizing more regular therapy for shorter durations; however, there is no consensus on the optimum SET program at present. Also, face-to-face programs can be complemented with mhealth.

The cost of a typical 3-month SET program is approximately £288 (£232–345) per person; this includes the cost of physiotherapists, technician staff, room hire, equipment rental, and specialist nurses (data from 2010).⁵⁰ Although the cost-effectiveness of TBT is not well researched, given recent inflation and typical costs of mobile phone applications, TBT may be more economically accessible. The costs associated with the devices and mhealth applications need to be considered and calculated.

Limitations

This review focused on studies using TBT, either wearable activity monitors, or mhealth platforms. Although there are four^{29,32,40,42} studies that have used mhealth platforms, this was not sufficient to generate a reasonable comparison between the different types of monitoring. Although wearable activity monitors are useful in monitoring physical activity, their ability to change certain health behaviors and encourage adherence is limited. However, mhealth applications can provide real-time feedback, symptom management, communication forums, and goal settings. Owing to the lack of these applications on the market, further analysis could not be conducted in this review. Conversely, several mhealth applications have been developed for patients with PAD, but are still undergoing clinical trials^{51–54}. Therefore, a further update to

this review is required when the mhealth applications have been launched and trialed.

Another limitation is the short durations, as only two studies^{36,37} assessed outcomes at 12 months of intervention and one study assessed at 6 weeks.²⁷ As PAD is a chronic, progressive disease, the functional outcomes need to be investigated for a longer period of time to ascertain the long-term effects. This is crucial as Normahani et al.³⁶ reported a plateau in the improvements of MWD at 12 months and McDermott et al.²⁸ observed no improvements in the 6MWT at 9 months.

Adherence was reported by less than half of the included studies. Both Gardner et al.^{26,34} studies observed high adherence rates in the TBT group (83% in 2011 and 81% in 2014) and similar rates in the SET group (85% in 2011). Endicott et al.³⁸ also reported that 43% did not use the activity monitor for more than a month due to loss of the device and withdrawal. Nicolai et al.³⁷ reported 28.9% of nonuse as well. Fukaya et al.³¹ also reported compliance rates: 88% in the intervention groups and 71% in the control group. Bearne et al.⁴¹ reported adherence using the Exercise Adherence Scale (EAS), specific for prescribed home exercise. A significant difference was only noted at 3 months between the TBT and control groups ($p = 0.01$); however, compared to baseline, a significant improvement was noted in the TBT group. Waddell et al.⁴³ reported only 53.5% of the daily step count was met or exceeded by participants. Unfortunately, the other studies failed to report adherence and compliance rates. As uptake and compliance to SET is already low, it is imperative to identify whether the SET barriers can be resolved using TBT-applied HBET. Therefore, future investigations need to be conducted into compliance and the barriers to adherence.

Conclusion

This systematic review provides evidence that tracking-based technology (TBT) can significantly improve walking. TBT can also improve QoL, therefore suggesting that TBT can be a useful adjunct in the management of patients with claudication. These findings are supportive in fueling the future introduction of TBT in home-based exercise therapy in PAD treatment guidelines with appropriate guidance from healthcare professionals. Future studies should be conducted that compare different types of TBT, optimal programs, and the impact of different components such as online exercises. An increased understanding of patient uptake, compliance, and adherence rates is required in future research to improve the effectiveness of these interventions.

Declaration of conflicting interests

The authors disclosed the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Professor Philip Stather is CEO of Walk-A-Cise Ltd and has produced a mobile phone application to deliver virtual supervised exercise therapy. There has been no data from that application incorporated in this study. All remaining authors have no affiliations with or involvement in

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Supplemental material

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