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Changes in walking abilities measured on a treadmill and in a community outdoor setting in patients with claudication: preliminary results

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Abstract

Background: *The aim of the study is to assess changes in walking abilities measured on a treadmill and in a community outdoor setting after 12-week supervised treadmill training in patients with claudication due to peripheral arterial disease.*

Material and methods: *The study included 36 patients aged 69.94 ± 6.9, randomised into training (n = 21) and control (n = 15) groups. Changes in pain-free walking distance ($PFWD_{TT}$), maximal walking distance (MWD_{TT}) during the graded treadmill test and the maximal walking distance (MWD_{GPS}), total walking distance (TWD_{GPS}), average walking distance (AWD_{GPS}), walking speed (WS_{GPS}), number of stops (NS_{GPS}) and stop durations (SD_{GPS}) obtained the during community setting outdoor walking were assessed before and after the programme.*

Results: *Significant results were observed only in the training group. $PFWD_{TT}$ and MWD_{TT} were prolonged by 92% and 97%, respectively ($p < 0.05$). AWD_{GPS} and SD_{GPS} increased significantly, which was accompanied by a reduction in NS_{GPS} ($p < 0.05$).*

Conclusions: *The 12-week, supervised treadmill training improves walking abilities measured on a treadmill, and partially in a community setting outdoor among patients with claudication.*

Keywords: global positioning system; intermittent claudication; peripheral arterial disease; treadmill; walking

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Introduction

Peripheral arterial disease (PAD) is one of the three major clinical manifestations of atherosclerosis, along with myocardial infarction and stroke [1]. This pathological condition involves stenosis or occlusion of the arteries responsible for supplying blood to the lower extremities [2]. Fontaine's classification describes four progressive stages in the development of PAD. Initially, the disease may be asymptomatic (stage I). However, in PAD stage II, intermittent claudication becomes a characteristic symptom. The subsequent stages of advanced PAD include rest pain (stage III) and the development of ischaemic ulcers or gangrene (stage IV) [1]. Individuals in the latter two stages of PAD progression are characterised as having chronic limb-threatening ischaemia [3].

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Intermittent claudication (IC) is manifested by pain in the muscles of the lower limbs while walking and its disappearance after cessation of exercise [4]. Assessing the abilities of walking is the basic element of comprehensive evaluation concerning a patient with intermittent claudication due to peripheral arterial disease. To date, the most frequently used tools to assess post-training changes in walking distance among this group of patients are treadmill walking trials [5], 6-Minute Walk Test (6MWT) [6] or subjective assessment of the patient using the Walking Impairment Questionnaire (WIQ) [7].

During walking tests in patients with intermittent claudication, 2 specific variables are measured: pain-free walking time or distance (PFWT/PFWD) and maximal walking time or distance (MWT/MWD), preventing the continuation of exercise [8]. Among the above-mentioned variables, MWT/MWD has the greatest reliability [9].

Global positioning system (GPS) technology has been frequently used to assess outdoor walking in both healthy individuals [10–12] and among patients with intermittent claudication [13–18], multiple sclerosis [19], following stroke [20, 21], spinal injury or stenosis [22, 23]. The evaluation of human walking in patients with claudication included variables such as maximal walking distance (MWD_{GPS}) — measured between two stops, walking speed (WS_{GPS}), number of stops (NS_{GPS}), stop duration (SD_{GPS}), and total walking distance (TWD_{GPS}). In several studies, the accuracy [10, 11, 17], reliability [24] and validity [10, 12, 17, 25] of these tests has been indicated. Moreover, in the study by Le Faucheur [17], a strong ($r = 0.81$) correlation between MWD_{GPS} and MWD measured on a treadmill (MWD_{TT}) was observed in patients with intermittent claudication. Despite the numerous advantages of using GPS technology to assess outdoor walking impairments among patients with intermittent claudication, to date, in only 2 studies has this tool been used to assess the effects of the intervention (revascularisation) [13] or, in contrast, to observe the condition of patients not undergoing any treatment [15].

In patients with intermittent claudication participating in the training model recommended in the guidelines [26], significant improvement in walking ability is observed. This improvement is typically 100% [27–29]. The tool most frequently used in the assessment of walking ability is the "Gardner/Skinner" incremental treadmill protocol [4]. However, it is not clear whether the improvement obtained during the treadmill walking test translates into equally high improvement in performing normal everyday walking. The specificity of walking on a treadmill involves the need to maintain constant, rhythmic gait, adapted to the constant pace of the treadmill. As noted by McDermott et al. [30], this forced, artificial walking does not necessarily translate to easier movement in a natural environment where curbs, uneven pavements, etc. must be overcome. So far, there have been no studies in which it would be assessed whether the training model recommended in the guidelines [26] improves the ability to walk outdoors. Therefore, the aim of the study was to check whether patients with intermittent claudication participating in supervised walking training on a treadmill experience a change in outdoor walking abilities and to verify if these changes in outdoor walking abilities are similar to those evaluated during the treadmill marching test.

Materials and methods

Study population — inclusion and exclusion criteria

The study included patients aged 50 and above, diagnosed with PAD (grade 2 according to the Fontaine classification), with a stable walking distance of 100–300 metres, ABI at rest < 0.9, undergoing standard pharmacological treatment (anti-platelet therapy, anti-hypertensive therapy, cholesterol-lowering agents) — no significant changes within the 6 months preceding the research programme or during its duration. None of the patients took pentoxifylline, cilostazol or selective cox-2 inhibitors. Patients have been recruited from the vascular outpatient clinic. The exclusion criteria were: unstable angina, history of myocardial infarction, undergoing vascular surgery within 1 year prior to the study, cardiovascular disorders, neurogenic claudication, cancer, kidney and liver diseases and osteoarthritis limiting mobility. Eligible patients were randomised to 1 of 2 groups: group T — training, C — control.

The study was approved by the Bioethics Committee of Karol Marcinkowski Medical University in Poznan (resolution number: 387/15). Each patient provided informed consent to participate in the research before the investigation.

Treadmill training

Treadmill training was performed in accordance with TASC II guidelines [26]. The patients participated in 12-week supervised treadmill training (SET), 3 times a week. During each exercise session, treadmill walking was performed at a speed 3.2 km/h and individually matched the grade that induced moderate claudication within 3–5 minutes. The initial grade was based on the entry treadmill tests results. Patients were asked to stop walking when claudication pain is considered moderate (moderate pain is a submaximal ischaemic pain felt in the lower limb/limbs at level 4 on the 5-point pain intensity scale, where 1 = no pain, 2 = onset of claudication, 3 = mild pain, 4 = moderate pain, and 5 = maximal

pain) [31]. Therefore, the patient started walking with no pain, and after the onset of claudication pain, walking was continued until it was considered moderate. When moderate pain occurred the treadmill was stopped and the patient rested in a sitting position until claudication lessened and then, treadmill walking was resumed. Each session of intermittent treadmill walking exercise was applied for 35 minutes at the beginning of the programme (repeated walking and resting phases), with a progressive increase in the session time by 5 minutes per every 2 weeks. At the following sessions, the treadmill grade was increased when the patient was able to walk for 8 minutes or longer with the previous workload. Neither a warm-up nor a cool-down was performed. A physical therapist administrated the 12-week supervised treadmill training. It was a one-on-one, face-to-face exercise session.

Control

The control group was instructed according to standard preventive recommendations (based on TASC II guidelines for the modification of risk factors regarding Peripheral Arterial Disease) [26] and did not undergo walking training.

Treadmill testing

Before the first treadmill test, the patients were familiarized with the specificity of walking on the treadmill. Familiarisation consisted of walking on a flat treadmill (inclination angle of 0%) at a speed of 3.2 km/h without inducing pain. The effort was interrupted when pain occurred. In such a case, the patient rested while sitting in a chair until the pain completely subsided — an average of about 5 minutes, and then walked on the treadmill once more. In total, the patient had to walk for no less than 6 minutes. This is the time when differences between repeated measurements of specific parameters cease to be statistically significant [32]. Pain free walking distance ($PFWD_{TT}$) and maximal walking distance (MWD_{TT}) were measured using the Gardner protocol [7] before and after the training programme. The test was carried out on a treadmill at a constant speed of 3.2 km/h and an initially on flat treadmill (inclination angle of 0%). Every 2 minutes, the inclination of the treadmill was raised by 2%. The patient reported when pain was experienced ($PFWD_{TT}$). The test was interrupted when maximal pain (= 5 on the 5-point pain intensity scale) symptoms appeared (MWD_{TT}). The treadmill test was repeated the next day. The better result from the 2 tests was selected for analysis.

Outdoor Walking Test

This test was performed using a watch with GPS (Forerunner® 310XT, Garmin, USA) and a heart rate sensor. The sensor, which was installed on a chest strap, was placed on the subject's chest. The test lasted 60 minutes. In front of the building, the device was turned on 10 minutes before beginning the test for initialisation of the system. This is twice as long as the maximal time required for detection by satellites [17]. During this time, the patient rested in a sitting position. The device was worn on the wrist of the non-dominant hand. Patients were instructed to walk for 60 minutes at their usual pace (self-selected, usual pace) and to stop solely in the case of lower limb pain preventing them from continuing the exercise. The patient was not instructed at what intensity of pain he should stop walking. The patient did not have to wait for the pain to completely dissipate. The patients pressed the "lap" button on the device each time they stopped because of pain and when they began walking after rest. The study took place in the city park next to the university. There are flat walking paths and benches in the park. The patients could choose any path. The park is car-free. By showing patients a convenient place to undergo an outdoor walking test, and thanks to the presence of a physical therapist who started the GPS device prior to the test, it was made easier for patients to participate in the test and minimise the number of invalid trials (e.g. due to improperly activating the device). The recorded data was transferred to a computer and then analysed. The following variables were used for the analysis: maximal walking distance (MWD_{GPS}) measured between 2 stops, total walking distance (TWD_{GPS}), average walking distance (AWD_{GPS}), average walking speed (WS_{GPS}) calculated from all walking bouts, number of stops (NS_{GPS}) and average stop durations (SD_{GPS}). The final walking bout was not taken into account for the calculation of MWD_{GPS} or WS_{GPS} due to the fact that it could be related to the desire to reach the university building where the test was ended. For example, the patient may have slowed down as the claudication increased to avoid severe pain forcing him/her to stop again at the end of the test.

At the end of each outdoor testing day, recordings from the GPS device were downloaded onto the computer using the Garmin Express application. The results were analysed by a trained operator. Test-retest reliability of the outdoor marching test using the Garmin Forerunner® 310XT has been validated in the authors' previous research [12]. The weather conditions during each test, such as wind speed, precipitation and temperature were recorded from the local weather station.

GPS-Specific Questionnaire (modified)

The GPS-specific questionnaire was created by Gernigon et al. [16]. In the original version, the questionnaire included questions about where the stroll took place, the estimated number of stops during the stroll, whether the patients had to stop for any reason other than limb pain, and whether the stroll reproduced usual limb pain, the level of difficulty in organising the stroll, finding an appropriate flat area for its performance, starting the GPS device, maintaining a regular walking pace and strolling for a minimum of 1 hour. Due to the fact that our patients had a previously designated place performing the test and the GPS device was activated by a physiotherapist, the respondents were asked only 4 questions from the questionnaire. Two of them were about the estimated number of intervals during the test, whether the patients had to stop for any reason other than limb pain and if walking reproduced limb pain. In the final 2 questions, the patients were asked to mark the level of difficulty in maintaining a regular walking pace, and walking for a minimum of 1 hour. The patients choose from among the following 4 levels: (1) very difficult, (2) rather difficult, (3) rather easy and (4) very easy.

Outdoor walking test was performed twice — before the programme and after it completion. The GPS-specific questionnaire was carried out only once, immediately after ending the 1st outdoor walking test. The tests were conducted by a qualified physical therapist, blinded to the group assignment of the patients.

Statistical analysis

The results were analysed statistically (Statistica 13.0). A t-test power analysis determined that at least 36 subjects were required to obtain a power of 0.8 at a two-sided level of 0.05 with an effect size of $d = 0.8$ [33]. This analysis was based on data derived from previous literature [34]. The Shapiro-Wilk test was used to assess the normality of the distribution of the variables. Changes in variables over 12 weeks of the programme were analysed by repeated measures ANOVA (within subjects, between groups). One-way ANOVA was used to determine baseline between-group differences. Pearson's r correlation coefficient was used to check the power of the correlations between quantitative variables with normal distribution. Spearman's rho correlations were used to test the relationships between categorical variables. The data were expressed as means and SD. The differences were considered significant at the level of $p < 0.05$.

Results

In total, 46 participants aged 69.94 ± (7) years were enrolled in the study. From among them, 10 of the enrolled patients withdrew from participation during the trial (Fig. 1).

Ultimately, the study included 36 patients. In Table 1, the baseline characteristics of the patients from before the programme are presented. None of the included patients had undergone invasive treatment of the arteries in the lower limbs, either surgically or through endovascular procedures, prior to their inclusion in the study.

After 12 weeks, significant changes in the treadmill and outdoor walking test were observed only in the training group. In the walking test on the treadmill, a significant increase was noted for $PFWD_{TT}$ and MWD_{TT} (maximal walking distance) (92% and 97%, respectively, $p < 0.05$). In the outdoor walking test, there was an increase in AWD_{GPS} (37%, $p < 0.05$) and a decrease in the number of stops among patients, accompanied by a prolongation of stop durations ($p < 0.05$). Differences between the training and control group in the above-mentioned variables were statistically significant ($p < 0.05$). The results are presented in Table 2.

On the basis of completed questionnaires, it was found that 100% of the respondents experienced claudication during the 60-minute outdoor walking test. The mean declared number of stops among the patients was 5 ± 3. Two patients reported that they had stopped once for reasons other than lower limb pain. A significant correlation was observed between the number of stops declared by the patients and stops recorded by the GPS device ($R = 0.74$, $p < 0.05$). The mean difference between the number of stops declared by the patients and those recorded by the GPS device was 2 stops, therefore it appears that the participants under-reported the number of actual stops. Maintaining a regular walking pace during the outdoor walking test was reported as rather difficult (45% patients) or rather easy (48% patients). For 7% patients, it was very easy. The task to walk for 60 minutes was considered rather difficult by 48% patients, rather easy by 38%, and very difficult or very easy by 7% patients.

Discussion

According to the authors' knowledge, this is the first study in which GPS technology has been used to assess the effects of SET (supervised treadmill training) in patients with intermittent claudication. Additionally, in the evaluation of the results of the outdoor walking test, a previously unused variable was proposed — AWD_{GPS}. The results obtained in this study indicate an ambiguous

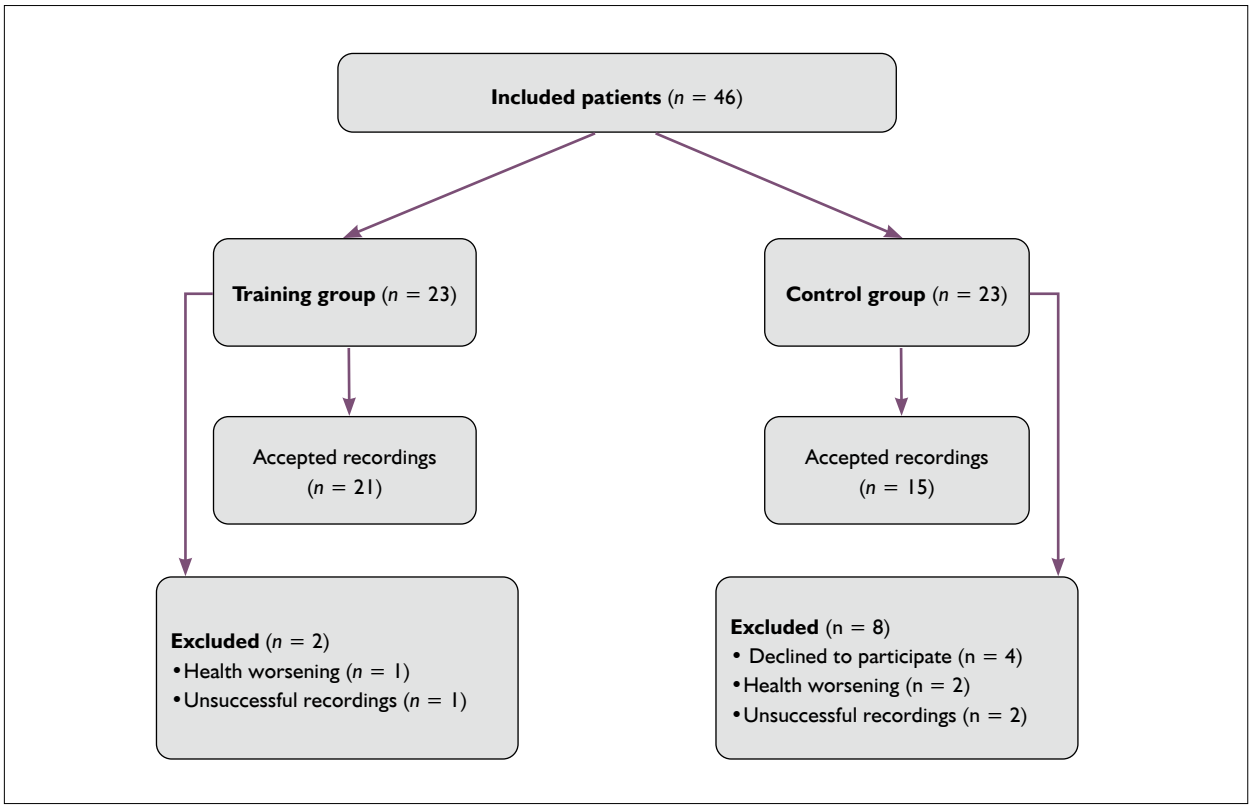

Figure 1. Flow diagram presents Patients through consecutive stages of the study and causes of Patients' exclusion

Table 1. Characteristics of the patients from before the programme

Characteristics	Training (n = 21)	Control (n =15)	p
Age [years]	69.14 ± 5.8	71.07 ± 8.4	0.4691
Height [cm]	166.43 ± 10.6	168.13 ± 12.7	0.6649
Body mass [kg]	74.81 ± 12.6	76.02 ± 15.3	0.7675
BMI [kg/m^2]	26.91 ± 3.1	26.81 ± 3.5	0.9254
Gender (F/M)	9/12	6/9	0.9866
Current smoker, n (%)	9 (43%)	5 (33%)	0.7363
Education (primary/secondary/higher)	1/8/12	0/9/6	0.3722
Nature of work (employee/retired-pension)	3/18	3/12	0.7851
Diabetes, n (%)	2 (10%)	3 (20%)	0.7508
ABI	0.71 ± 0.2	0.73 ± 0.2	0.7281

BMI — body mass index; F — female; M — male; ABI — ankle brachial index

effect of SET on improving the ability to walk in outdoor areas among patients with intermittent claudication. On the one hand, patients experienced significant lengthening of AWD_{GPS} and SD_{GPS}, as well as significant reduction in NS_{GPS} ($p < 0.05$), while on the other hand, no significant influence of SET was demonstrated on the MWD_{GPS}, TWD_{GPS} and WS_{GPS} variables ($p > 0.05$). The studied patients taking part in SET reported that they felt improvement in daily functioning, such as the possibility of walking to a tram stop or garage without stopping due to lower limb pain, which was not possible before training. It may be concluded that the first--time use of the AWD_{GPS} variable in this work, better reflected everyday walking in a natural environment among patients with intermittent claudication than the previously proposed MWD_{GPS} variable. It is also worth noting that in the training group, after 12 weeks, the average AWD_{GPS} came close to the average MWD_{GPS} (baseline: 0.54 vs 0.73 km, after 12 weeks: 0.74 vs 0.77 km; data presented in Table 2). Perhaps the sections of

Table 2. Changes in analysed variables after 12 weeks in the training and control groups

Variable	Group	Before the programme (mean, SD)	p^1	After the programme (mean, SD)	p^2	Change (mean, SD)	p^3
$PFWD_{TT}$ [km]	T	0.12 ± 0.1	0.0653	0.23 ± 0.1	0.0002	0.11 ± 0.1	0.0074
	C	0.15 ± 0.1		0.19 ± 0.1	0.1822	0.04 ± 0.0	
MWD_{TT} [km]	T	0.29 ± 0.1	0.0742	0.57 ± 0.2	0.0002	0.28 ± 0.2	0.0004
	C	0.38 ± 0.1		0.41 ± 0.2	0.9644	0.03 ± 0.2	
MWD_{GPS} [km]	T	0.73 ± 0.5	0.8166	0.77 ± 0.4	0.9933	0.04 ± 0.5	0.9645
	C	0.77 ± 0.3		0.82 ± 1.0	0.9919	0.05 ± 1.0	
TWD_{GPS} [km]	T	2.60 ± 0.4	0.4323	2.56 ± 0.5	0.9684	–0.04 ± 0.4	0.8644
	C	2,73 ± 0.5		2.66 ± 0.6	0.9247	–0.07 ± 0.5	
AWD_{GPS} [km]	T	0.54 ± 0.2	0.2884	0.74 ± 0.3	0.0301	0.20 ± 0.2	0.0055
	C	0.52 ± 0.3		0.39 ± 0.2	0.1121	–0.12 ± 0.2	
WS [kph]	T	3.46 ± 0.4	0.9461	3.41 ± 0.3	0.7604	–0.05 ± 0.3	0.9554
	C	3.45 ± 0.5		3.35 ± 0.3	0.8028	–0.10 ± 0.4	
NS_{GPS} [n]	T	6.74 ± 4.7	0.6229	5.11 ± 3.5	0.0348	–1.63 ± 1.9	0.0009
	C	5.64 ± 3.4		7.21 ± 3.8	0.1031	1.57 ± 3.1	
SD_{GPS} [s]	T	129.53 ± 67.6	0.2992	162.89 ± 60.9	0.0422	33.37 ± 78.4	0.0387
	C	144.57 ± 52.8		125.71 ± 50.5	0.3122	–18.86 ± 52.4	

p^1 value between training group and control group at baseline

p^2 value among group before and after 12 weeks

p^3 value between change in training group and control group

T — training group; C — control group; TT — results obtained during treadmill test; GPS — results obtained during outdoor walking test; $PFWD_{TT}$ — pain—free walking distance; MWD_{TT} — maximal walking distance; MWD_{GPS} — maximal walking distance; TWD_{GPS} — total walking distance; AWD_{GPS} — average walking distance; WS_{GPS} — walking speed; NS_{GPS} — number of stops; SD_{GPS} — stop duration

the road that patients need to cover once every day are shorter than MWD_{GPS}, hence, the subjective feeling of improvement after training, with no significant changes in MWD_{GPS}. The lack of significant SET effect on the TWD_{GPS} and WS_{GPS} variables may be connected with the methodology used in the work during the outdoor test. It is possible that in shorter sections and without the burden of walking for 60 minutes, patients are able to walk faster. Unfortunately, the questionnaire used in the study (GPS-specific questionnaire) does not allow to clearly indicate whether the 60-minute walking load is an easy or rather difficult task. Recommendations to walk for 60 minutes was perceived as rather or very difficult by 55% of patients, and to maintain a regular pace as rather difficult by 45% of patients. Similar or even more emphasized results were reported by Gernigon et al. [16]. The authors raised the issue to determine the shorter but simultaneously optimal walking time that is sufficient to provide valid data on walking ability. Perhaps a less than 60-minute test time will allow to avoid phenomena such as stopping for reasons other than claudication. In the present study, stops for reasons other than lower limb pain were reported by 2 patients. Although the location selected for testing was without car traffic or traffic light, taking the advice of other researchers into account, influence on the remaining factors was limited, i.e. stopping to answer the phone or the need to use the restroom during the test.

It is noteworthy that in the control group not subjected to any intervention, MWD_{GPS}, AWD_{GPS} and TWD_{GPS} remained unchanged. In turn, in the research by Klonizakis et al. [15], it was demonstrated that over a 6-month period, patients not undergoing any intervention demonstrated significantly shorter measured GPS, mean and maximal walking distances. However, their observation time was twice as long as in this study, which may indicate that the 3-month period is too frequent patient monitoring to assess the progression of claudication. It would be advisable to conduct further research on a larger number of patients, the results of which would allow to indicate the appropriate frequency of monitoring the functional state of patients.

After completion of the 12-week supervised treadmill training introduced in the authors' study, in the examined patients, a significant increase in $PFWD_{TT}$ and MWD_{TT} was noted (by 92% and 97%, respectively). These results stay in agreement with previous studies performed by other authors. In the meta-analysis by

Gardner et al. [27], it was shown that the amount of post-training improvement for both of the above variables is more than 100% (120% for PFWT and 180% for MWT). In turn, in a systematic review by Parmenter et al. [28] a range of 79–422% was indicated in post-training improvement for PFWT, and 106% to 151% for MWT. Treat-Jacobson et al. [9] reported that after participating in supervised walking training on a treadmill, the MWT extended by 3.4 to 4.6 minutes, and PFWT by 1.65 to 2.2 minutes, compared to the control group. It is worth noting that in the study by Le Faucheur [17], a strong ($r = 0.81$) correlation between MWD measured on a treadmill (MWD_{TT}) and MWD_{GPS} was observed in patients with intermittent claudication. There may be reservations that the observed improvement in MWD_{TT}, with a simultaneous lack of changes in MWD_{GPS} and the significant but lower improvement of AWD_{GPS} (37% vs 97%) compared to MWD_{TT}, may be related to the specificity of training and treadmill testing. However, it should be emphasized that in this study, prior to the first treadmill test, a familiarisation, recommended by other authors [30, 31], was performed. Moreover, baseline treadmill test was repeated twice, which also decreases the potential learning effect from the treadmill test. As emphasized by Hiatt et al. [30], with a properly performed test and taking into account the best result from the baseline tests, the patient cannot exceed his/her own true pathophysiologic limitation for a graded treadmill test. Moreover, in the works by Bulińska et al. [35] and Rosłoniec et al. [36], it was shown that patients with intermittent claudication who trained Nordic Walking achieved similar improvement in MWD_{TT} as patients involved in standard treadmill training. An interesting observation would be to verify the relationship between MWD_{GPS}, AWD_{GPS} and functional claudication distance measured on a treadmill (FCD_{TT}). FCD, defined as the distance at which a patient prefers to stop because of claudication pain, was shown to be a reliable and valid variable [37]. Perhaps this variable, measured in laboratory conditions, would be a better reflection of outdoor walking abilities in IC patients.

The rest duration between consecutive walks may undoubtedly be of clinical significance for the patient. Interestingly, in his study [38], Gardner observed significant differences in onset of claudication and time to maximal claudication pain after treadmill walking according to different protocols, but the time needed for claudication pain relief was similar. In turn, Faucheur et al. [18] noticed that the duration of rest in the outdoor walking test is the main factor determining the duration of the walk to the next stop; however, in subsequent studies [13] this observation was not confirmed. In the research by Hersant et al. [39], a correlation was observed between haemodynamic recovery time after exercise in patients with claudication and maximal walking distance. Taking the above reports and the mechanisms of post-training improvement in walking distance [40, 41] described in the literature into account, a reduction in the duration of rests could be expected among patients, especially if MWD_{GPS} and TWD_{GPS} remained unchanged. However, surprisingly, a significant increase in SD_{GPS} was observed in the patients who underwent treadmill walking training in this study. This change was accompanied by a significant reduction in NS_{GPS}. It may be assumed that a patient who leads a predominantly sedentary lifestyle does not experience claudication. And if s/he performs even little effort and pain occurs quickly, the patient rests often, but also briefly, because the deficit is small. With higher intensity of a single effort, longer resting period can be expected, but also less frequent stops. Perhaps the AWD_{GPS} elongation observed in this work was a factor increasing the lead during a single effort. A similar effect may be caused by walking speed (WS). It is worth noting that in the research by Gernigon et al. [13], analysing the single stroll for each patient, it was observed that the WS variable remained relatively stable, while the remaining ones were characterised by vast variability. There was a suggestion that after the intervention, in the next test, the subject could cover the same distance, but in a much shorter time. In fact, among PAD patients undergoing revascularisation, a significant increase in WS was observed 6 months after surgery (0.3 ± 0.5 kph) [13]. However, the results of the authors' research for patients undergoing walking training do not allow to support the above-hypothesis. In both groups, WS did not change significantly.

Conclusions

In conclusion, the results obtained in this work, for the first time, indicate the potential beneficial effect of SET on improving walking ability among patients with intermittent claudication in a natural environment. In evaluating the results of the outdoor test, it is worth using the additional variable proposed by the authors — AWD_{GPS} — because it seems that it better reflects the everyday walking in a natural environment among patients with intermittent claudication than the previously proposed MWD_{GPS} variable.

Study limitations

The study has several limitations that should be acknowledged. Firstly, the evaluation of therapy effects did not include vascular measurements. This absence renders the study purely descriptive, lacking an assessment of possible underlying mechanisms.

The authors relied on the subjective assessments of participants undergoing training, who reported improvements in walking within community settings. These assessments were based on the ability to walk to various locations such as garages, bus stops, and shops; however, the specific distances covered during these segments remain unknown. Future studies may benefit from measuring these distances and correlating them with the results of the outdoor tests. Furthermore, introducing complementary tools, such as questionnaires, could help to systematically collect data on patients' subjective experiences regarding the therapy effects. The use of Google Maps to assess walking distances in real-world walking environments is an interesting suggestion for future research [42].

Article information and declarations

Data availability statement: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.
Ethics statement: The approval for the study was given by the Bioethics Committee of Karol Marcinkowski Medical University in Poznan (resolution number: 387/15). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.
Author contributions: All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Anita Kulik, Ewelina Dušek, Przemysław Madejski, Anna Spannbauer, Piotr Mika, Jerzy Trzeciak. All authors read and approved the final manuscript.
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