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The PAD-adapted 30-20-10 during Nordic walking

A new exercise training session in patients with symptomatic peripheral artery disease

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Abstract

This study aimed to investigate the feasibility of a peripheral artery disease (PAD)-adapted 30-20-10 Nordic walking session in patients with symptomatic PAD and to compare the cardiovascular response of this new training session to a traditional walking (TW) and 4 × 4 minutes Nordic walking session. This is a prospective observational study. Patients with Fontaine stage II PAD were included. Patients participated in Nordic walking sessions, which were randomly assigned as TW, 4 × 4 minute intervals, and peripheral artery disease adapted 30-20-10 exercise session (PAD-adapted 30-20-10 sessions). PAD-adapted 30-20-10 and 4 × 4 minutes sessions consisted of 4 repetitions of 4 minutes of effort followed by 3 minutes of passive recovery. PAD-adapted 30-20-10 session was characterized by 4 continuous 1-min repetitions at 3 different walking speeds [high (30 seconds), moderate (20 seconds) and low (10 seconds)]. During the 4 × 4 minutes session, patients were asked to cover the maximal distance at a constant speed. During TW session, patients were asked to walk at a speed inducing moderate-to-severe claudication pain. Heart rate, rating of perceived exertion (RPE) and claudication pain intensity using a visual analog scale were assessed. The perceived enjoyment of each session was assessed using a visual analog scale ranging from 0 (not enjoyable) to 10 (very enjoyable). Eleven patients with chronic symptomatic PAD were included (62 ± 13 years; 54% women). The mean heart rate during the time of effort was significantly higher in PAD-adapted 30-20-10 group than in 4 × 4 minutes and TW groups (127 ± 12, 122 ± 12, 114 ± 11 bpm, respectively; $P \leq .001$). The mean rating of perceived exertion (16 ± 1, 15 ± 1, 13 ± 1; $P \leq .001$) and claudication pain intensity (8 ± 1, 7 ± 1; 7 ± 1 mm; $P \leq .019$) were significantly higher during PAD-adapted 30-20-10 sessions than during 4 × 4 minutes and TW sessions. The perceived enjoyment was similar among sessions (8.7 ± 1.6 for TW, 8.6 ± 1.7 for 4 × 4 minutes, and 8.8 ± 1.8 mm for PAD-adapted 30-20-10 sessions; $P = .935$). The PAD-adapted 30-20-10 session is feasible and induces higher cardiovascular stimulation and claudication pain than 4 × 4 minutes and TW procedures in patients with symptomatic PAD. Despite these different responses, a similar perceived enjoyment among the sessions has been shown. Future investigations are needed to examine the effects of this new training session in these patients.

Abbreviations: 6MWD = 6-minute walking distance, 6MWS = 6-minute walk test mean speed, 6MWT = 6-minute walk test, CVD = cardiovascular diseases, HIIT = high-intensity interval training, HR = heart rate, HR_{peak} = peak heart rate, LMM = linear mixed model, PAD = peripheral artery disease, PAD-adapted 30-20-10 = peripheral artery disease adapted 30-20-10 exercise session, RPE = rate of perceived exertion, SET = supervised exercise training, TW = traditional walking, VAS = visual analog scale.

Keywords: cardiovascular response, exercise training, vascular rehabilitation, walking performance.

1. Introduction

Peripheral artery disease (PAD) is a chronic vascular disease characterized by the narrowing and/or occlusion of lower limb arteries, leading to decreased blood flow.[1] Claudication is a typical symptom of PAD and is defined as pain/cramping appearing during exertion with relief after a few minutes of rest.[1] Claudication induces a significant decrease in functional ability and quality of life.[2]

Supervised exercise training (SET) is the first-line therapy in patients with PAD.[1–6] To optimize training adaptations, training frequency should be at least 3 sessions/week for at least 3 months, and each session should last at least 30 minutes.[2,4–6] Patients are

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usually asked to walk at a speed that elicits moderate-to-severe claudication pain (traditional walking, TW).[2,4–6] It is, however, important to note that claudication pain severity does not necessarily depend on common measures of exercise intensity [heart rate (HR), oxygen uptake (VO_2), rate of perceived exertion (RPE)].[3] A moderate-to-severe claudication pain during exercise may correspond "only" to moderate exercise intensity.[3,7]

Methods of prescribing exercise intensity are underused to individualize exercise training in patients with PAD.[3] Recently, 2 meta-analyses demonstrated the superiority of vigorous exercise training on cardiorespiratory fitness[3,8] and walking performance improvements,[3] suggesting the importance of exercise intensity monitoring during SET to optimize outcomes.

High-intensity interval training (HIIT) is characterized by short, repeated bouts of exercise performed at a vigorous intensity interspersed by periods of active or passive recovery.[9] There is a growing interest in HIIT supported by a robust and continually expanding body of research, which demonstrates its effectiveness in enhancing cardiovascular and metabolic profiles in patients with cardiovascular diseases (CVD).[10–14] The Norwegian 4 × 4 minutes model, which consists of high-intensity intervals at 85% to 95% of peak heart rate (HR_{peak}) interspersed with 3-minute periods of active recovery, represents the most common long-duration and high-volume HIIT protocol in patients with CVD.[15] While this topic remains equivocal, long-duration HIIT protocols have been shown to significantly increase peak oxygen uptake (VO_{2peak}) to a greater extent than short-duration (≤1 minute) HIIT protocols in patients with CVD.[15] This could potentially be attributed to more pronounced central adaptations resulting from longer interval durations.[15] Notably, long and short-duration HIIT protocols resulting in a higher total energy expenditure have also been shown to significantly improve vascular function.[16]

There is limited evidence of the effectiveness of HIIT in patients with symptomatic PAD,[3,17] and as of now, no optimal HIIT protocol has yet been established. Based on the knowledge of the effectiveness of long-duration HIIT protocols in patients with CVD, it could be hypothesized that this approach may also be a promising training strategy for patients with symptomatic PAD. However, based on our clinical experience, the 4 × 4 minutes training method may be moderately tolerable for patients with symptomatic PAD due to claudication pain occurring during high-intensity exercise intervals, which can make it challenging or even impossible to sustain the high-intensity bout. Pain during the 4-min exertion often leads patients to gradually reduce walking speed, thereby limiting the ability to achieve (or maintain) high-intensity exercise for the 4-min effort duration. If one aims to implement a long-duration HIIT protocol in patients with PAD, another training approach should therefore be considered.

A promising long-duration HIIT approach is the 10-20-30 method, first developed by Gunnarsson and Bangsbo and tested in moderately trained runners.[18] The 10-20-30 method consists of alternating sprint/maximal, high and low intensity exercises performed for 10 seconds, 20 seconds and 30 seconds (for a total of 1 minute), respectively, 5 times. This set is repeated 3 to 4 times during the training sessions interspersed by 2 minutes of passive rest.[18] This HIIT approach has also been recently tested on a cycle-ergometer in older patients with type 2 diabetes,[19] hypertension,[20] and asthma.[21] Alternating between short-term exercise at high (or maximal) intensity and a progressive decrease in intensity, 4 to 5 times, during long interval bouts, highly stimulates the cardiovascular system inducing a high percentage of HR throughout the session.[22] Also, starting with a higher workload and decreasing it over time and having multiple workload variations during the exercise bouts may decrease the time to achieve the high-intensity domain, increase the time spent close to VO_{2peak}, and increase the exercise tolerance during exercise bouts.[18,23,24] These responses to exercise may account for the significant improvements in VO_{2peak} observed following this training regimen, despite a 50% reduction in training volume.[18] Notably, in several populations, the 10-20-30 method has also been shown to be effective in improving blood pressure, lipid profile, glycemic control, and body composition.[18–20] These adaptations could be particularly relevant for patients with PAD, as they often exhibit low VO_{2peak} levels[3] (which are associated with increased mortality rates[25]) and high-risk cardiovascular profiles.[1] However, since walking is the most recommended training modality in patients with PAD,[6] an adapted version of this training session should be considered. Indeed, for safety reasons mainly related to the well-known balance disorders,[26,27] sprint exercises are not recommended, especially when sessions are performed outdoors. Therefore, starting the set with 30 seconds at high intensity, followed by 20 seconds at moderate intensity, and 10 seconds at low intensity seems more adapted to this population (peripheral artery disease adapted 30-20-10 exercise session, PAD-adapted 30-20-10). The 30 seconds of exercise performed at high intensity allows a substantial increase in the HR. Then, the 20 seconds of exercise performed at moderate intensity is useful to maintain HR at higher levels despite a decrease in exercise intensity. Finally, the 10 seconds of exercise performed at low intensity may act as an active recovery phase and will allow patients with PAD to manage claudication pain during exertion and better tolerate high exercise intensities.

The first aim of this study was to investigate the feasibility of a PAD-adapted 30-20-10 Nordic walking exercise session in patients with symptomatic PAD. The second aim was to compare the HR, RPE, claudication pain intensity, internal training load, and perceived enjoyment between this training session and TW and 4 × 4 minutes exercise sessions.

It was hypothesized that PAD-adapted 30-20-10 Nordic walking session would induce a higher cardiovascular response than either TW or the 4 × 4 minutes sessions.

2. Materials and methods

2.1. Patients

Patients with symptomatic chronic atherosclerotic PAD were recruited from the University Hospital of Lausanne (CHUV), Switzerland. As described elsewhere,[28–30] all the participants were enrolled in the Angiofit study (prospective observational cohort study) and took part in a 3-month SET program (see Supplementary STROBE Checklist, http://links.lww.com/MD/M920). All patients underwent cardiac screening to exclude contraindications to exercise. This study was approved by the local ethics committee and was conducted following the Declaration of Helsinki. Patients participated voluntarily and gave informed written consent before entering the study.

2.2. Experimental design

Each participant performed (1) a routine vascular examination prior to SET, (2) a 6-minute walk test before SET and at the end of each month of SET, and (3) 3 different Nordic walking exercise sessions during the 2nd and 3rd months of SET (Fig. 1).

2.3. Clinical routine vascular examination

The medical history was assessed. Body mass index, cardiovascular risk factors, and ongoing treatment were also recorded. Resting ankle-brachial and toe-brachial indices were measured.[1]

2.4. Six-minute walk test

The 6-minute walk test (6MWT) consists of walking the longest possible distance in 6 minutes in a 50 m corridor to determine the 6-minute walking distance (6MWD).[31]

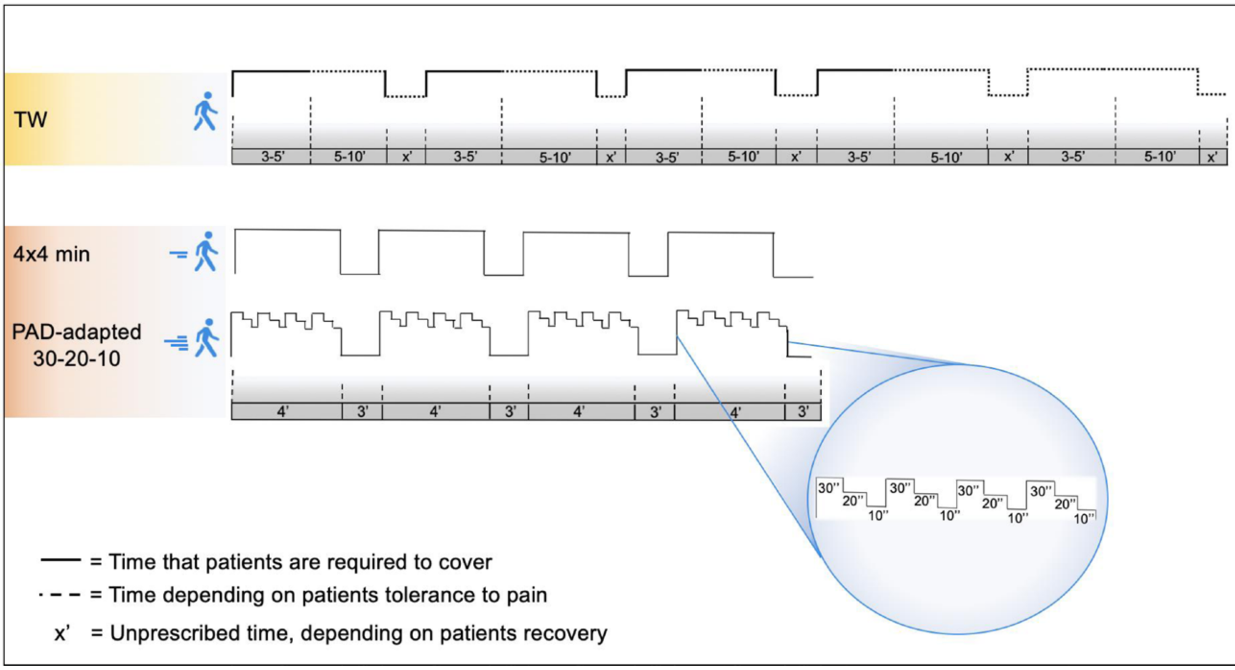

Figure 1. Description of the 3 experimental training sessions. TW = traditional walking, PAD = peripheral artery disease.

2.5. Nordic walking exercise training sessions

All sessions were conducted outdoors within the hospital perimeter in a Nordic walking modality over 100 m of level ground. At the beginning of the training program, all patients received instructions on the proper use of the poles.[30] Each patient participated to the 3 different exercise sessions which were randomly assigned by a computer-generated random list. The order of the sessions was as follows: 1st session: 4 patients performed TW, 3 patients performed 4 × 4 minutes, 4 patients performed PAD-adapted 30-20-10; 2nd session: 4 patients performed TW, 4 patients performed 4 × 4 minutes, 3 patients performed PAD-adapted 30-20-10; 3rd session: 3 patients performed TW, 4 patients performed 4 × 4 minutes, 4 patients performed PAD-adapted 30-20-10.

Although during training programs the training intensity is usually determined based on the claudication pain,[6] in the present investigation, for 4 × 4 minutes and PAD-adapted 30-20-10 sessions, we sought to revise and innovate this approach by prioritizing the individualization of training mainly based on objective parameters. Here, we used the results obtained from a functional evaluation, 6MWT, to prescribe the training sessions and monitor the exercise intensity and the walking speed. Because of the relative novelty of these methods, 2 stages of familiarization were conducted before performing each modality as follows: (1) during the first month of SET, patients performed a lead-in period of low-moderate intensity; (2) the first sessions of 4 × 4 minutes and PAD-adapted 30-20-10 were performed at 100% of 6MWT mean speed (6MWS), corresponding to 30 seconds at high speed in PAD-adapted 30-20-10 session. This approach has facilitated the implementation of these training sessions at a safe intensity. Thereafter, the percentage of 6MWS was individually increased at each 4 × 4 minutes and PAD-adapted 30-20-10 session to achieve the fastest and most tolerable and feasible session that each patient was able to complete. The different walking speeds and distances were individually targeted and were adapted to the patients' capacities. The definitive sessions were reached after 2 to 3 attempts. The longest TW session duration and the fastest and most feasible 4 × 4 minutes and PAD-adapted 30-20-10 sessions were considered for the analyses. The percentage of 6MWS was based on the results of the closest 6MWT.

Traditional walking session. The target session duration was 30 to 60 minutes. Patients were asked to walk at a self-selected speed inducing moderate-to-severe pain within 3 to 5 minutes, leading to stopping the effort within 5 to 10 min[2]. Then, patients rested until pain resolution before resuming walking (Fig. 1).

4 × 4 *minutes session*. The 4 × 4 minutes session consisted of 4 repetitions of 4 minutes interval bouts alternated with 3 minutes of passive recovery (Fig. 1). During each 4-min bout, patients were asked to cover the maximal distance at constant speed. For example, if 6MWD was 400 m (6MWS = 1.11 $m \cdot s^{-1}$), the distance corresponding to 105% of the 6MWS for 4 minutes of effort was 280 m. Every distance remained identical for each repetition.

PAD-adapted 30-20-10 session. The PAD-adapted 30-20-10 session was characterized by 4 continuous 1-minute repetitions at 3 different walking speeds [high (30 seconds), moderate (20 seconds) and low (10 seconds)] (Fig. 1). For example, if 6MWD was 400 m (6MWS = 1.11 $m \cdot s^{-1}$), the distances could have been 43 m for 30 seconds (130% 6MWS), 22 m for 20 seconds (100% 6MWS) and 5.5 m for 10 seconds (50% 6MWS). Every distance remained identical for each repetition.

2.6. Measures

Heart rate. During all sessions, HR was continuously measured using a traditional chest strap monitor (Polar M430, Finland), and the mean session HR of total effort time was calculated. The mean HR of the last 30 seconds of each repetition was also calculated.

Rate of perceived exertion and claudication pain. Immediately after each repetition, patients were asked to rate their RPE on Borg's scale (6–20)[32] and their pain intensity on a visual analog scale (VAS) [0 (no pain) to 10 (maximal pain)].[33] The mean RPE and pain intensity of each session were calculated.

Internal training load. The internal training load of each session was calculated as the product of the total session (effort and recovery) time and the mean RPE of the session.[34]

Perceived enjoyment. As previously described,[35] the perceived enjoyment was assessed following each training session using a VAS ranging from 0 (not enjoyable at all) to 10 (very enjoyable). Ten minutes after each training session, patients were asked to rate their perceived enjoyment by responding to the question: "How did you enjoy the training session?."

2.7. Statistical analysis

The experimental variables among the training sessions were evaluated with a linear mixed model (LMM) [session (TW, 4 × 4 minutes, PAD-adapted 30-20-10) × repetitions]. The fixed effects included session and repetitions, while the participants were set as a random effect. Since the number of repetitions was not identical among the training sessions (see Results), LMMs for the HR of the last 30 seconds of each repetition, RPE and claudication pain intensity were performed on the first 4 repetitions only. When a session, repetition, or session × repetition interaction effect was found, multiple comparisons with Bonferroni adjustment were performed. For the mean session HR of total effort time, mean RPE and claudication pain intensity, internal training load and perceived enjoyment of the training sessions, LMMs were used to compare the main session effect. When a session effect was found, multiple comparisons with Bonferroni adjustment were performed.

The level of significance was set at $P < .05$. SPSS 27 software (IBM Corporation, Armonk, NY) was used to perform all statistical analyses.

3. Results

3.1. Patients

Eleven patients with symptomatic chronic PAD were included (Table 1). 6MWD was 547.8 m (±80.3 m). All patients completed all 3 sessions, and no adverse events occurred during or related to the sessions.

3.2. Exercise sessions

The descriptions of the exercise sessions are presented in Table 2. LMM analysis revealed a significant fixed session effect for the internal training load ($P \leq .001$). Multiple comparisons analyses showed that the internal training load was significantly higher in TW session than in 4 × 4 minutes ($P \leq .001$) and PAD-adapted 30-20-10 sessions ($P = .005$), and that the internal training load was significantly higher in PAD-adapted 30-20-10 session than in 4 × 4 minutes session ($P = .008$, Table 2).

Table 1

Patients characteristics at baseline.

Number of patients	11
Women (n)	6 (54)
Age (years)	61.9 (± 12.7)
Body mass index (kg · m^{-2})	23 (± 3.6)
Ankle-brachial index	0.77 (± 0.17)
Toe-brachial index	0.66 (± 0.25)
Prior revascularization (n)	3 (27)
Cardiovascular risks factors	
Hypertension (n)	6 (54)
Dyslipidemia (n)	10 (90)
Smoking	
Current (n)	4 (36)
Former (n)	6 (54)
Never (n)	1 (9)
Family history (n)	5 (45)
Type 2 diabetes (n)	2 (18)
Ongoing treatment	
Antiplatelet (n)	11 (100)
Anticoagulant (n)	1 (9)
Lipid lowering (n)	9 (81)
Antidiabetic (n)	2 (18)
Antihypertensive (n)	7 (63)

Data are presented as mean ± SD or n (%).

3.3. Heart rate

Figure 2 displays HR of a representative patient during the 3 training sessions. LMM analysis revealed a fixed session effect for mean session effort HR ($P \leq .001$). Multiple comparisons showed that the mean HR during effort time was significantly higher in PAD-adapted 30-20-10 (127 ± 12 bpm) and 4 × 4 minutes (122 ± 12 bpm) sessions than in TW (114 ± 11 bpm; $P \leq .001$) session and that there was no significant difference between PAD-adapted 30-20-10 and 4 × 4 minutes sessions ($P = .060$).

There were significant fixed session and repetition effects for the mean HR of the last 30 seconds of each repetition (Fig. 3). Multiple comparisons showed that HR was significantly higher in PAD-adapted 30-20-10 (1st repetition: 132 ± 15 bpm; 2nd repetition: 137 ± 14 bpm; 3rd repetition: 139 ± 16 bpm; 4th repetition: 141 ± 17 bpm) and 4 × 4 minutes (1st repetition: 126 ± 15 bpm; 2nd repetition: 131 ± 15 bpm; 3rd repetition: 131 ± 15 bpm; 4th repetition: 135 ± 15 bpm) sessions than in TW session (1st repetition: 117 ± 12 bpm; 2nd repetition: 118 ± 12 bpm; 3rd repetition: 119 ± 14 bpm; 4th repetition: 117 ± 13 bpm; $P \leq .001$). The value in PAD-adapted 30-20-10 session was significantly higher than that in 4 × 4 minutes session ($P \leq .001$). Multiple comparisons also showed that HR at the 3rd and 4th repetitions was significantly higher than HR at the 1st repetition ($P \leq .017$). There was no significant session × repetition interaction effect ($P = .643$).

3.4. RPE

The mean session RPE was 13 ± 1 for TW, 15 ± 1 for 4 × 4 minutes and 16 ± 1 for PAD-adapted 30-20-10 ($P \leq .001$). Multiple comparisons showed that the mean RPE was significantly higher in PAD-adapted 30-20-10 and 4 × 4 minutes sessions compared to TW ($P \leq .001$); in addition, the mean RPE in PAD-adapted 30-20-10 sessions was significantly higher compared to that in 4 × 4 minutes sessions ($P = .012$).

There were significant fixed session and repetition effects with a significant session × repetition interaction effect in RPE (Table 3). Multiple comparison analyses showed that RPE during PAD-adapted 30-20-10 session was significantly higher than that during 4 × 4 minutes and TW sessions (Table 3). Similarly, RPE during 4 × 4 minutes sessions was significantly higher than RPE during TW (Table 3). Multiple comparison analyses also showed that during PAD-adapted 30-20-10 session, RPE at the 2nd, 3rd, and 4th repetitions was significantly higher than RPE at the 1st repetition ($P = .041$, $P \leq .001$, $P \leq .001$, respectively; Table 3). Additionally, RPE at the 4th repetition was significantly higher than RPE at the 2nd repetition ($P = .003$; Table 3). Similarly, during 4 × 4 minutes session, the RPE at the 3rd and 4th repetitions was significantly higher than the RPE at the 1st repetition ($P = .014$, $P \leq .001$, respectively; Table 3). Additionally, RPE at the 4th repetition was significantly higher than RPE at the 2nd repetition ($P = .014$; Table 3). During the TW session, RPE was found to be unchanged from the 1st and 4th repetitions ($P = 1.000$).

3.5. Claudication pain intensity

The mean session claudication pain intensity was 7 ± 1 mm for TW, 7 ± 1 mm for the 4 × 4 minutes and 8 ± 1 mm for PAD-adapted 30-20-10 sessions ($P = .055$).

Table 2

Exercise session description.

	TW	4 × 4 minutes	PAD-adapted 30-20-10
Number of repetitions, range	4.6 (3–6)	4	4
Distance covered, m	2845 (±580)	1552 (±164)	1565 (±229)
Total effort time, min and s	33 minutes 5 seconds (±3 minutes 57 seconds)	16 minutes	16 minutes
Total rest time, min and s	8 minutes 52 seconds (±2 minutes 37 seconds)	12 minutes	12 minutes
Internal training load, a.u.	530.9 (±61.4)	430.5 (±34.8)*	464.2 (±22.1)*,†
Speed, range	1.0–1.7 $m \cdot s^{-1}$ (87–102% 6MWS)	1.2–1.8 $m \cdot s^{-1}$ (98–116% 6MWS)	*30 seconds* 1.6–2.7 $m \cdot s^{-1}$ (120–145% 6MWS) *20 seconds* 1.1–2.0 $m \cdot s^{-1}$ (90–115% 6MWS) *10 seconds* 0.5–1.0 $m \cdot s^{-1}$ (40–70% 6MWS)

6MWS = mean 6-min walking speed, PAD = peripheral artery disease, range = minimum to maximum, SD = standard deviation, TW = traditional walking.
*Significantly lower than TW.
†Significantly higher than 4 × 4 minutes.

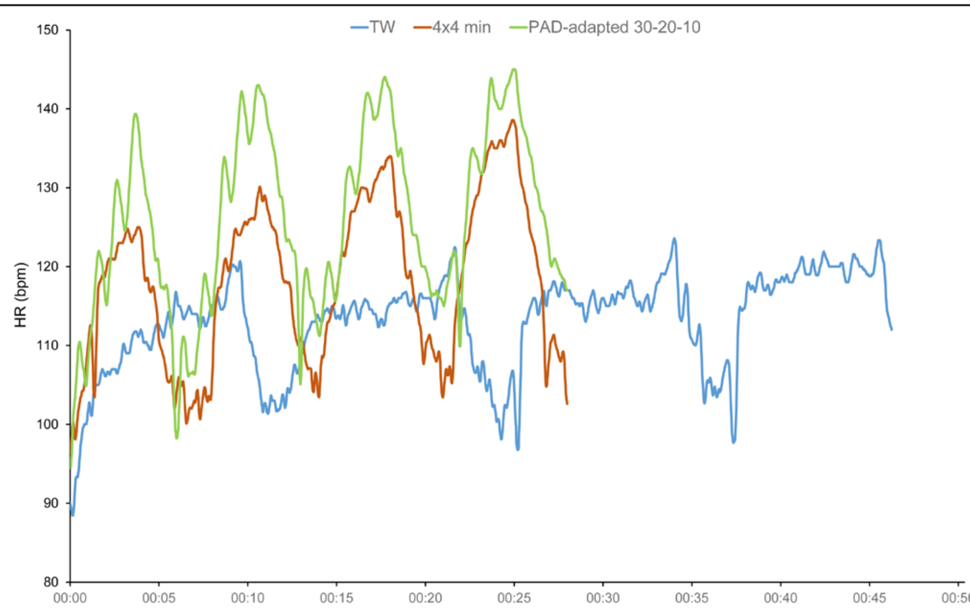

Figure 2. Heart rate (HR) of a representative patient for the 3 training sessions. This patient performed 4 repetitions during the traditional walking (TW) session. PAD = peripheral artery disease.

There were significant fixed session and repetition effects with no significant session × repetition interaction effect on claudication pain intensity (Table 3). Multiple comparison analyses showed that the claudication pain intensity was significantly higher during the PAD-adapted 30-20-10 session compared to the 4 × 4 minutes ($P < .001$) and TW session ($P = .019$) (Table 3). There was no significant difference between the 4 × 4 minutes and TW sessions ($P = .634$) (Table 3).

3.6. Perceived enjoyment

There was no significant session fixed effect on perceived enjoyment (8.7 ± 1.6 mm for TW, 8.6 ± 1.7 mm for 4 × 4 minutes, and 8.8 ± 1.8 mm for PAD-adapted 30-20-10 sessions; $P = .935$).

4. Discussion

The main findings of this study confirmed our hypotheses and showed that PAD-adapted 30-20-10 is feasible in patients with PAD. The results also showed that the claudication pain intensity and the objective (HR) and subjective (RPE) cardiorespiratory response were significantly higher in PAD-adapted 30-20-10 than in 4 × 4 minutes and TW sessions. HR and RPE were also significantly higher in 4 × 4 minutes session when compared to TW. Notably, despite these different responses,

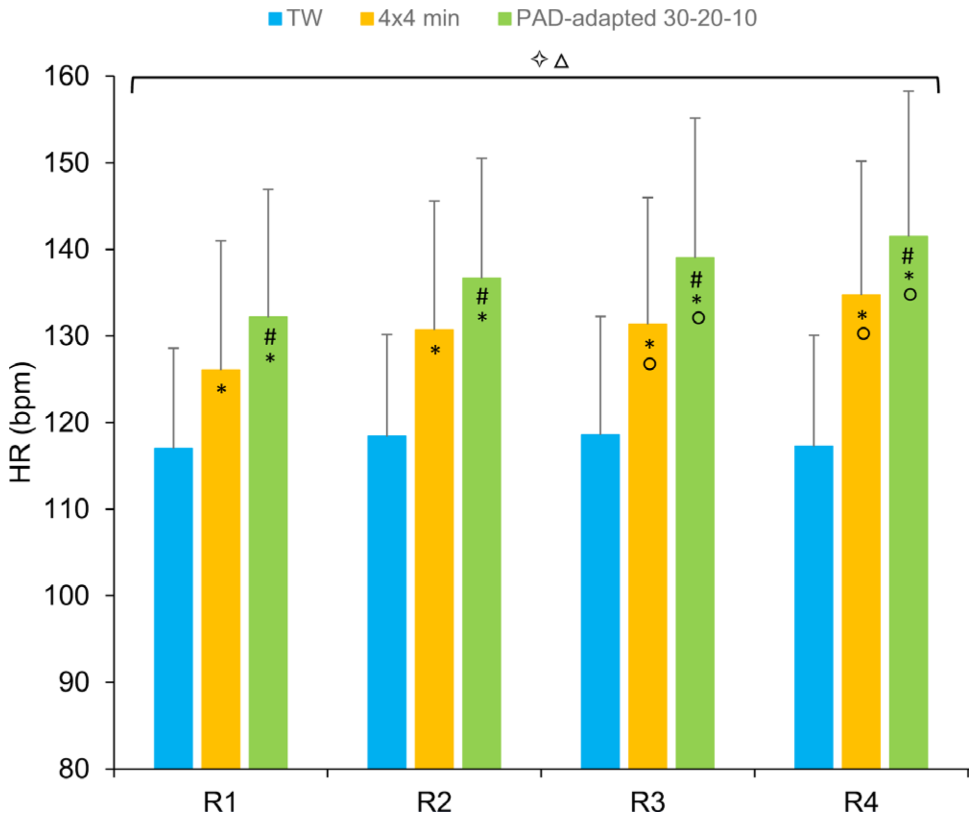

Figure 3. Mean heart rate (HR) for each training session during the last 30 seconds of each repetition (R). ✧ for significant fixed session effect; △ for significant fixed repetition effect; * significantly higher than traditional walking (TW); # significantly higher than 4 × 4 minutes; ○ = significantly higher than R1. PAD = peripheral artery disease.

Table 3

Rate of perceived exertion (RPE) and claudication pain intensity during the 3 exercise sessions.

		Repetitions					*P*-values		
		R1	R2	R3	R4	Mean	Session effect	Repetition effect	Session × repetition
RPE (±SD)	TW	13 (±1)	12 (±1)	13 (±1)	13 (±1.5)	13 (±1)	≤.001	≤.001	.001
	4 × 4 minutes	14 (±2)	15 (±1)	15 (±2)*	16 (±2)*,†	15 (±1)			
	PAD-adapted 30-20-10	15 (±1)	16 (±1)*	16 (±1)*	17 (±1)*,†	16 (±1)			
Claudication pain intensity (±SD), mm	TW	7 (±1)	7 (±1)	7 (±1)	7 (±1)	7 (±1)	≤.001	.002	.050
	4 × 4 minutes	6 (±2)	7 (±1)	7 (±1)	8 (±1)	7 (±1)			
	PAD-adapted 30-20-10	7 (±1)	8 (±1)	8.0 (±1)	8 (±1)	8 (±1)			

Data are presented as mean ± standard deviation.
PAD = peripheral artery disease, R = repetition, SD = standard deviation, TW = traditional walking.
*Significantly different from the 1st repetition.
†Significantly different from the 2nd repetition.

a similar perceived enjoyment among the sessions has been shown. Finally, the results showed that the internal load was significantly higher in TW session than in 4 × 4 minutes and PAD-adapted 30-20-10 sessions.

The 3 exercise sessions were in line with the current guidelines for exercise training in terms of claudication pain intensity, reaching moderate-to-severe pain.[2,4,6] These findings indicate that similar levels of pain can be elicited with different training approaches than TW sessions. Furthermore, when prescribing 4 × 4 minutes and PAD-adapted 30-20-10 sessions, incorporating additional parameters such as HR, RPE, and percentage of 6MWS can enhance the accuracy in tailoring and monitoring of exercise intensity. This enriched approach may offer improved training session content for patients with PAD.[3,7] In these 2 sessions, the mean session HR was significantly higher than for TW, supporting the interest in using these sessions to increase the cardiorespiratory training stimulus.[3,8] In line with our hypothesis, PAD-adapted 30-20-10 training approach more effectively stimulates the cardiovascular system compared to 4 × 4 minutes session. This suggests that incorporating multiple workload variations during the exercise bouts can shorten the time required to reach the high-intensity domain, enabling patients to spend more time in this training zone (Fig. 2).[18,23,24] During 4 × 4 minutes session, patients did not reach the same walking speed as reached during the 30 seconds of the PAD-adapted 30-20-10 session, thus resulting in a lower cardiovascular response. With a faster walking speed, severe claudication pain may appear more quickly compared to walking at a slower walking speed, making it difficult to complete a constant-speed high-intensity 4-min walking bout. In contrast, during PAD-adapted 30-20-10 session, patients performed for a shorter time at high intensity followed by a decrease in intensity, which allowed the patients to better manage pain and therefore the completion of the 4 minutes of effort at a higher objective (HR) and subjective (RPE) intensity. In addition, performing at a higher walking speed, as seen in PAD-adapted 30-20-10 session, can lead to greater neuromuscular adaptations, which may be responsible for more significant performance improvements.[36] In the present investigation, patients did not perform a maximal or symptom-limited cardiopulmonary exercise test to assess VO_{2peak} and HR_{peak} and determine the relative training intensity (%HR_{peak}) of the training sessions. It is therefore difficult to establish if PAD-adapted 30-20-10 and 4 × 4 minutes sessions could be considered HIIT sessions.[9] Despite this, the mean RPE values for both sessions was greater than HIIT RPE cutoff of ≥ 15,[13] corroborating the high intensity of these sessions.

Compared to other cardiovascular conditions, HIIT has been less investigated in patients with PAD, especially during walking.[17] To our knowledge, only one study has investigated the long-duration HIIT protocol (4 × 4 minutes) during walking (treadmill) in these patients.[37] The training consisted of 4 4-min intervals of exercise performed at 90–95% HR_{peak} interspersed by 3 minutes of active recovery and is safe and effective in improving cardiorespiratory fitness, time to exhaustion, stroke volume and cardiac output. Other HIIT approaches with reduced interval duration, such as ten 2-min treadmill intervals performed at 80% to 100% VO_{2peak} interspersed by 2 minutes of passive recovery,[38] 8 2-min treadmill intervals performed at 90% HR_{peak} interspersed by 3 minutes of passive recovery,[39] 10 2-min intervals performed at 85% to 90% of limb-specific (upper or lower limb ergometers) VO_{2peak} interspersed by 2 minutes of passive recovery,[40,41] have also shown to be well tolerated and effective in improving walking performance in patients with PAD. Recently, Pymer et al[42] showed that a short-duration HIIT protocol consisting of 10 1-min cycling intervals performed at 85% to 100% HR_{peak} interspersed by 1 minute of passive recovery is a well-tolerated, safe, and effective HIIT approach. When conducting HIIT with patients with PAD, managing claudication pain is crucial for both patients and clinicians to ensure the training approach is feasible, especially during walking. While shortening the interval duration seems a logical HIIT manipulation in patients with PAD, the PAD-adapted 30-20-10 session allow the patients to highly stimulate that cardiovascular response and manage the pain during the long interval bout.[15] This underscores the crucial need for future research to determine the optimal HIIT protocol (short vs long) for these patients.

It is interesting to note PAD-adapted 30-20-10 session elicits a higher claudication pain intensity compared to 4 × 4 minutes and TW sessions. High levels of pain during traditional training have been found to induce lower completion and adherence rates during exercise programs when compared to alternative modalities (pain-free walking, arm ergometry, resistance training and circuit training).[43] However, no data exist on the difference of completion and adherence rates following moderate exercise intensity and HIIT approaches in patients with PAD. Compared to low-to-moderate intensity sessions, high-intensity sessions are shorter in duration. Interestingly, previous questionnaire survey showed equal preference for short duration/high-intensity and long duration/moderate intensity in these patients.[44] This is in line with our finding showing that the perceived enjoyment was very high and similar among the 3 exercise sessions, despite the levels of pain were higher in PAD-adapted 30-20-10 session. This could be related to the fact that (i) PAD-adapted 30-20-10 session may be more stimulating for patients, as they achieve greater walking speeds during the training, which could be especially satisfying for them; (ii) the training volume and internal load was lower compared to TW session. While it is difficult to ascertain the impact of these results on future training adherence, these results highlight the importance of considering all at once pain, perceived enjoyment, and training volume and intensity in long-term training adherence. Taken together, our results advocate for future studies investigating functional, physiological, and subjective (self-reported health-related quality of life) adaptations of this new training approach in patients with PAD.

Study limitations. First, patients were using poles during the exercise sessions, whereas 6MWT was performed without poles. This choice was made to ensure 6MWT standardization[31] and to ensure patient safety during the exercise sessions. Walking with poles also induces higher cardiovascular stimulation.[45] Additionally, since each patient was his own control, the comparison among the 3 training sessions was not compromised. Second, because of the relatively high level of walking performance of the included patients, the application of these results cannot be generalized to patients with more severe PAD. In these cases, a lighter version of this training approach could be applied using an adapted version of 5-10-15 training method.[46] In fact, this latter has been investigated and used in untrained individuals, demonstrating beneficial effects.[46]

5. Conclusions

The results presented herein showed that PAD-adapted 30-20-10 session is feasible and induces higher cardiovascular stimulation and claudication pain than 4 × 4 minutes and TW sessions in patients with symptomatic PAD. Interestingly, despite these different responses, a similar perceived enjoyment among the sessions has been shown. Future investigations are needed to examine the effects of this new training session in these patients as well as long-term adherence.

Author contributions

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