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Impact of a 12-Week Telecoaching Aerobic Training Program in a Green Environment on Quality of Life and Migraine Frequency: A Pilot Study

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ABSTRACT

Growing evidence indicates that aerobic exercise can be considered among the nonpharmacological strategies for migraine management. The present pilot study investigated the effects of a 12-week telecoaching (TC) aerobic exercise, performed in a green environment, on migraine-related outcomes. The primary endpoint regarded headache characteristics, while quality of life (QoL) and physical activity levels were considered secondary outcomes. At baseline (T0), participants' physical activity level and QoL were evaluated using the International Physical Activity Questionnaire (IPAQ) and the Migraine-Specific QoL Questionnaire (MSQ) v2.1. The study sample consisted of 20 individuals (18 females, mean age 48.95 ± 12.17 years). The intervention consisted of a structured, progressive walking program of moderate intensity, performed three times per week. Exercise duration progressively increased from 30 to 50 min across the 12-week intervention period. The subjects showed relatively high baseline physical activity levels that remained stable over time (total MET 4121.39 ± 8961.93 vs. 5399.45 ± 5968.58, $p = 0.275$). Migraine intensity did not change significantly (mean numeric rating scale [NRS] 5.86 ± 1.41 vs. 5.50 ± 2.14, $p = 0.570$). In contrast, subjects reported a significant improvement in migraine frequency, with a reduction in headache days over different recording windows (13.50 ± 7.29 vs. 11.40 ± 6.88, $p = 0.012$). Multivariate analysis did not reveal significant changes in secondary outcomes, including MSQ score. Overall, the results of such a pilot study confirm how a TC-based aerobic exercise intervention may reduce headache frequency in physically active individuals with migraine. Nevertheless, the approach did not modify migraine intensity or QoL but may still support general good health maintenance.

1 | Introduction

Migraine is a widespread neurological disorder affecting approximately 15% of the general population, although its true prevalence may be underestimated due to frequent misdiagnoses [1]. Furthermore, studies assessing diseases' impact on life have recognized migraine as the leading cause of years lived with disability in individuals between 15 and 49 years [2]. Migraine management involves both acute medications to stop headache episodes and (when needed) preventive drugs to reduce their frequency over time. However, traditional preventatives may not be accepted by patients because of their side effects or stigma toward some drug classes [3–5]. Indeed, some traditional oral preventatives are antiseizure drugs that may induce a sense of brain fog or blurred vision, while others are tricyclic antidepressants, which can lead to weight gain and drowsiness. Despite the recent introduction of anti–calcitonin gene–related peptide (anti-CGRP) with high efficacy with very few side effects, a significant part of patients remains refractory [6]. Consequently, there is growing interest in identifying nonpharmacological interventions to alleviate the burden of migraine, including self-management strategies, manual therapy, and physical activity (PA) [7–9].

Still, the role of exercise in migraine remains controversial [10]. While some studies have suggested that exercise can trigger migraine attacks [11, 12], other research has consistently demonstrated its preventive benefits, including a reduction of the frequency and intensity of migraine episodes, as well as an improvement in quality of life (QoL) [13, 14]. Exercise intensity appears to be a key factor influencing this relationship. High-intensity activity, often associated with competitive sports, has been linked to headache episodes [12–14], where moderate-intensity exercise, more typical of general PA, is associated with protective effects [10]. This uncertainty regarding exercise's impact may contribute to the low PA levels commonly observed in individuals with migraine [15]. However, studies with multiple populations showed that higher PA levels correlate with reduced pain intensity, improved functionality, and enhanced QoL. Increasing evidence supports the implementation of aerobic exercise programs to reduce migraine frequency and severity [16–18]. For instance, Darabaneanu et al. demonstrated how a structured aerobic exercise program significantly reduced both the frequency of monthly migraine days and the intensity of attacks compared to standard care [19]. Furthermore, a recent meta-analysis reported small to moderate reductions in migraine episode duration and pain intensity following aerobic exercise interventions [16].

In this scenario, this pilot study is aimed at evaluating the effectiveness of a moderate-intensity aerobic exercise program conducted in a natural environment and supported by a telecoaching (TC) approach in individuals with migraine. TC refers to the use of digital technologies, including mobile devices and computers, to remotely manage and deliver exercise interventions [20]. Green exercise (GE) denotes PA performed in natural or urban green spaces, such as parks or campuses [21, 22]. The primary aim of this study is to investigate the impact of TC and GE on migraine characteristics, such as attack intensity and frequency. The secondary outcomes included the effects on QoL investigated using general and migraine-specific questionnaires, as well as the PA levels and body composition changes.

2 | Material and Methods

2.1 | Study Design

The present pilot study evaluated the feasibility and the possible effects of a TC–aerobic training program in a cohort of patients with migraine. Following the provision of written informed consent, participants underwent a 4-week screening period during which they were asked to complete a headache diary. Baseline assessment (T0) included a review of the headache diary and the administration of questionnaires regarding PA and migraine-specific outcomes. Subsequently, participants engaged in a 12-week TC intervention while continuing to complete the headache diary. Postintervention assessments were conducted at T1 (Week 12) using the same measures as at baseline. Further details regarding the study design can be found in Figure 1.

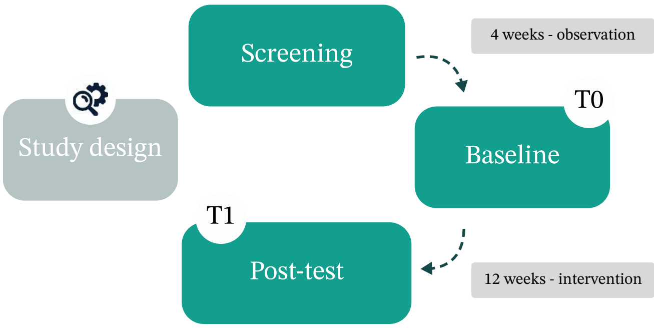

FIGURE 1 | Overview of the study design and assessment timeline.

2.2 | Participants

Participants were enrolled at the Headache Centre of the University Hospital "Paolo Giaccone" in Palermo, Italy. The study was designed and implemented by a multidisciplinary collaboration between exercise science researchers from the Sport and Exercise Sciences Research Unit at the University of Palermo and Neurologists specialized in headache management at the same institution. Eligibility criteria included adults aged 18–65 years with a clinically established diagnosis of migraine (episodic or chronic), according to the International Classification of Headache Disorders, 3rd edition (ICHD-3) [23]. Subjects were classified as affected by chronic migraine (CM) if they complained of 15 or more headache days per month (with at least 8 days fulfilling migraine criteria or requiring acute medication intake) for at least three consecutive months. Patients who did not fulfill the aforementioned headache frequency criteria were classified as affected by episodic migraine (EM). Participants were required to have a history of migraine for at least 1 year, with disease onset before the age of 50, and to report at least four headache days per month over the 3 months preceding enrolment. Regarding pharmacological treatment, participants not receiving preventive therapy were instructed not to initiate prophylactic medications during the study period while continuing standard acute treatment as clinically indicated. Individuals already on a stable preventive regimen for at least 3 months before enrolment were required to maintain the same treatment throughout the intervention. Additional inclusion criteria were willingness and ability to participate in a structured walking program three times per week, absence of medical contraindications to exercise, and basic digital literacy (e.g., ability to send emails and mobile messaging). Exclusion criteria included refusal or inability to provide the written informed consent, inability to complete the prescribed exercise, and inadequate digital skills to support remote monitoring procedures. Each subject had to provide written informed consent to be included and was free to withdraw from the study at any time without consequences. The study protocol was approved by the Ethics Committee Palermo 1 of the University Hospital "Policlinico di Palermo" (approval number: 04/2023) and was conducted according to the principles of the Declaration of Helsinki.

2.3 | Evaluations

Evaluations were performed at baseline (T0) and at the end of the intervention (T1) to determine the effects of the training program. The assessment framework included both clinical indicators and patient-reported outcome measures (PROMs). The battery of instruments comprised questionnaires specifically validated for use in migraine populations, such as the Headache Impact Test-6 (HIT-6) and the Migraine-Specific Quality of Life Questionnaire (MSQ). In addition, several well-established and widely applied tools in clinical research were administered, including the International Physical Activity Questionnaire (IPAQ), the Hospital Anxiety Depression Scale (HADS), the Beck Depression Inventory-II (BDI-II), and the Pittsburgh Sleep Quality Index (PSQI). These instruments are extensively validated and commonly used across clinical and research contexts, including studies involving individuals with migraine [24–27].

2.3.1 | Anthropometric Measurements

Anthropometric data were obtained using standardized procedures. Body weight was recorded using a Seca electronic scale (maximum capacity of 300 kg with a resolution of 0.1 kg; Seca, Hamburg, Germany), while stature was assessed using a stadiometer (maximum height of 220 cm with a resolution of 0.1 cm). All the measurements were performed with the participants barefoot, wearing light clothes, and standing upright with arms relaxed alongside the body. Body mass index (BMI) was subsequently calculated as weight in kilograms divided by the square of height in meters (kg/m^2).

2.3.2 | Headache Diaries

Patients were asked to record the occurrence of headache episodes on a weekly basis. In addition, they were instructed to report the average headache intensity using a numeric rating scale (NRS) that ranged from 0 (i.e., *no pain*) to 10 (i.e., *worst imaginable pain*). For this study, the primary headache-related outcomes were the mean number of headache days and the mean headache intensity, calculated over the 4 weeks of observation (T0) and over the final 4 weeks of intervention (T1). Based on the headache frequency, patients were diagnosed with EM or CM.

2.3.3 | IPAQ

The IPAQ is a widely used and validated tool for evaluating an individual's PA levels [28]. It provides an estimate of energy expenditure as metabolic equivalent of task (MET) minutes per week, based on participants' self-reported PA over the previous 7 days. The questionnaire captures information regarding the type, frequency, and duration of PAs performed at different intensity levels. Moderate-intensity activities are defined as exercise that produces significant increases in breathing rate, while vigorous-intensity activities are characterized by substantial exertion, limiting the ability to speak comfortably. According to total MET scores, participants are classified into three categories: (a) inactive (< 700 MET-min/week), (b) sufficiently active (700–2519 MET-min/week), and (c) highly active (≥ 2520 MET-min/week).

2.3.4 | PSQI

PSQI is a validated self-assessed instrument developed to study the quality of sleep during the preceding month. It includes 19 items organized into seven domains, including the subject's perceived sleep quality, the latency in falling asleep, sleep duration, any referred sleep disturbances, the use of possible sleep medications, and perceived daytime dysfunction. Every domain is rated on a 4-point Likert scale (0–3), with a questionnaire total score that ranges from 0 to 21. Lower scores indicate better sleep quality, while higher scores are indicative of more pronounced sleep disturbances. Due to its comprehensive structure and ease of use, the PSQI is extensively employed in research contexts to evaluate sleep-related impairments [29].

2.3.5 | HIT-6

HIT-6 is a reliable self-administered tool specifically developed to evaluate the burden of headaches on daily functioning over the previous 4 weeks. It evaluates six dimensions, which include headache intensity, the impact on social life, role functioning, vitality, concentration, and psychological distress. The overall score is the sum of the responses to the six items, and the total score ranges from 36 (i.e., *minimum impact*) to 78 (i.e., *severe impact*) [30]. Score interpretation is categorized as follows: Scores ≤ 49 denote no or little impact from headache, scores 50–55 indicate mild impact, scores 56–59 reflect moderate impact, and scores ≥ 60 are associated with severe functional impairment [31, 32].

2.3.6 | MSQ v2.1

The MSQ v2.1 is a patient-reported outcome measure designed to assess migraine impact on QoL during the preceding 4 weeks [33]. The instrument comprises 14 items, each scored on a 6-point Likert scale going from a minimum of 1 (i.e., *none of the time*) to a maximum of 6 (i.e., *all the time*), with higher scores suggesting a more marked detrimental effect of migraines on QoL. The MSQ assesses three principal domains of health-related QoL: role function-restrictive (RR), role function-preventive (RP), and emotional function (EF).

2.3.7 | HADS

The HADS is a self-administered instrument consisting of 14 items, each scored on a 4-point Likert scale (0–3), designed to identify and quantify symptoms of anxiety and depression in nonpsychiatric populations [34]. The questionnaire is divided into two subscales, with seven items assessing anxiety and seven assessing depression symptoms. Each subscale results in a total score that ranges from 0 to 21, with higher scores suggesting more severe symptoms.

2.3.8 | BDI-II

BDI-II is a self-delivered questionnaire developed to evaluate the grade of depressive symptomatology. It comprises 21 items, with each one rated on a 4-point Likert scale going from 0 to 3. The total score is obtained by the sum of all item responses, and higher scores reflect more severe depressive symptoms. Score interpretation leads to different categories: 0–13 means minimal depression, 14–19 indicates mild depression, 20–28 suggests moderate depression, and 29–63 can be interpreted as severe depressive symptoms.

2.4 | Intervention: TC–Aerobic Training

The TC–aerobic intervention consisted of a 12-week walking program, chosen due to its accessibility, safety, and well-established health benefits. Walking represents a widely accessible form of PA that has been consistently associated with a reduced risk of chronic diseases and related comorbidities. Participants performed the program independently in a green environment (e.g., parks or natural settings) while receiving remote supervision through the TC approach. The intervention was designed in accordance with current recommendations from the World Health Organization (WHO), ensuring a total weekly volume of 150–300 min of moderate-intensity PA per week. Training frequency was set at three sessions per week over 12 consecutive weeks, with a minimum recovery interval of 48 h between sessions. Each session was structured into three phases: a warm-up phase (~10 min), a central walking phase (~30–50 min), and a cool-down phase (~10 min). The warm-up phase included dynamic exercises performed from a standing position, such as shoulder circles, pelvic movements, foot circles, and trunk rotations (two sets of 10 repetitions each). The duration of the central walking phase was progressively increased throughout the intervention as follows: (a) Weeks 1–2: 30 min of walking; (b) Weeks 3–4: 35 min of walking; (c) Weeks 5–6: 40 min of walking; (d) Weeks 7–8: 45 min of walking; and (e) Weeks 9–12: 50 min of walking. The cool-down phase consisted of low-intensity exercise, including breathing control techniques and isometric contractions performed in different positions (two sets of 20 s each). A comprehensive overview of the intervention program is presented in Table 1.

TABLE 1 | Description of the training program.

Exercise	
Warm-up phase	Starting from a neutral standing position with legs slightly apart (NSP), participants performed a standardized series of dynamic exercises, including the following: - 2 Ss of 10 Rs of circling movements of shoulders (forwards and backward) - 2 Ss of 10 Rs of clockwise (CC) and anticlockwise (AC) circling movements of the pelvis with hands to the hips - 2 Ss of 10 Rs of upper limbs FEM - 2 Ss of 10 Rs of low limbs FEM
Central walking phase	During the central walking phase, the participants perform free walking in a green environment, with the following setting: - 1st and 2nd weeks: 30 min of walking (4.5–6.0 km/h) - 3rd and 4th weeks: 35 min of walking (4.5–6.0 km/h) - 5th and 6th weeks: 40 min of walking (4.5–6.0 km/h) - 7th and 8th weeks: 45 min of walking (4.5–6.0 km/h) - From 9th to 12th weeks: 50 min of walking (4.5–6.0 km/h)
Cool-down phase	- From NSP with both arms behind the back and clasped fingers, stretch the entire body. 2 Ss for 10–20 s - From NSP, bend the trunk forward slowly. 2 Ss for 10–20 s - From NSP, bend the knee, put the hands around the foot, and pull it toward the body. Stretch your quadriceps. 2 Ss for 10–20 s - From NSP, lateral flexion stretches with arm above the head. 2 Ss for 10–20 s

Abbreviations: AC, anticlockwise; CC, clockwise; FEM, flexion–extension movements; NSP, neutral standing with legs slightly apart; Rs, reps; Ss, sets.

2.5 | TC Strategies

A structured TC approach was implemented for the entire duration of the training program to enhance participant engagement and adherence. The TC strategy comprised one scheduled phone call and two motivational text messages per week, designed to reinforce compliance with the exercise program. Before the initial intervention, all participants received comprehensive instructions during videoconferencing sessions led by qualified coaches. To support proper execution of the training program, each participant was provided with an exercise manual containing both visual and textual guidelines for correctly performing the warm-up and cool-down exercises. In addition, a training diary was distributed to record adherence to each session and to document the weekly frequency of migraine episodes. These support tools were intended to facilitate effective communication between participants and telecoaches and to assist in the planning and monitoring of individual exercise sessions. The TC-based aerobic training program was supervised by certified professionals in sport and exercise science, maintaining a telecoach-to-participant ratio of 1:10. Telecoaches remained available throughout the 12-week intervention to address any questions or concerns expressed by participants.

2.6 | Statistical Analysis

Data distribution was initially evaluated with the Shapiro–Wilk normality test. Since the data were not normally distributed, the median and the interquartile range (IQR) were reported alongside the mean and standard deviation (SD) for descriptive purposes. Changes in primary outcomes (i.e., headache days and pain intensity) from preintervention (T0) to postintervention (T1) were assessed using the repeated-measures Wilcoxon signed-rank tests. For outcomes showing significant effects, Bonferroni correction was applied to adjust for multiple comparisons. Secondary outcomes (BMI, HIT-6, BDI-II, HADS-A, HADS-D, total METs, PSQI, MSQ total score, RR, RP, and EF) were analyzed using a repeated-measures general linear model, with time (pre vs. post) as the within-subject factor and the 11 measures entered as dependent variables. When a significant multivariate effect of time was observed, subsequent univariate repeated-measures analyses were conducted for each outcome variable to identify specific changes over time. The frequency of qualitative information, such as migraine diagnosis (i.e., EM vs. CM), between the two time points was studied using a χ^2 test. The analyses were performed using the computer software Jamovi (the Jamovi project, Version 2.3.28) and IBM SPSS Statistics v29.0.1.0. Tests were considered statistically significant if $p < 0.05$. Due to the exploratory nature of the study, no a priori sample size calculation was initially performed. However, a power analysis conducted using G*power (paired-samples t-test approximation) indicated that a minimum sample size of 28 participants would be required to achieve adequate statistical power ($\alpha = 0.05, 1\text{-}\beta = 0.80$).

3 | Results

A total of 20 participants were included in the study, comprising 18 females (90%) and 2 males (10%). The mean age was 48.95 ± 12.17 (median = 50.00, IQR 47.00–56.00). Mean height was 1.63 ± 0.07 m (median = 1.62, IQR 1.60–1.67). Data on weight and BMI are reported in Table 2 and Figure 2, showing minimal changes observed between baseline (T0) and postintervention (T1). All the participants (100%) completed the 12-week intervention without any reported adverse event or injury.

The Wilcoxon signed-rank test showed a significant improvement from pre- to postintervention for the headache frequency as the primary outcome ($p = 0.012$) but not for headache intensity ($p = 0.570$). Table 3 and Figure 3 show the results of migraine characteristics at baseline and postintervention, highlighting the significant reduction in headache frequency. In addition, a post hoc correlation analysis using Spearman's rho did not reveal any significant association between the number of headache days and either weight ($p = 0.875$) or BMI ($p = 0.353$). As far as clinical diagnoses based on headache frequency are concerned, there was a slight change from CM to EM in the two time points, although not significant (T0 CM: EM = 45%: 55%; T1 CM: EM = 30%: 70%; χ^2 test p value 0.327).

For the secondary outcomes, the multivariate test did not show a significant effect of time on the combined dependent variables (Pillai's trace = 0.55, $F = 1.67$, $p = 0.212$), demonstrating no statistically significant changes in these variables. Table 4 shows the scores of the included questionnaires. Even with the nonsignificant multivariate effect, follow-up univariate analyses were conducted for exploratory purposes to examine potential pre–post changes at the level of individual variables. Statistically significant pre–post differences for BMI ($p = 0.022$) were found, while no significant effects were observed for the remaining variables. To control for inflation of Type I error due to multiple comparisons, the p values from the univariate analyses were adjusted using the Benjamini–Hochberg false discovery rate (FDR) procedure. After applying the correction, the results did not reach statistical significance.

Even if the MET total score was already considered in the multivariate analysis of secondary outcomes showing nonsignificant variations between the two time points, we decided to further analyze the changes in PA parameters between T0 and T1 using the Wilcoxon signed-rank test. Even in this case, no significant variation was found pre- and postintervention (see Table 5 and Figure 4).

4 | Discussion

The present pilot study is aimed at assessing the effects of an aerobic training program, conducted in a GE and supported through TC, on migraine characteristics, QoL, and PA levels in patients with migraine. The benefits of TC and GE have been documented across various clinical populations, including individuals with neurodegenerative [35, 36], metabolic [37, 38], cardiovascular [39, 40], and psychological disorders [41, 42], as well as older adults [43–45]. Although TC and GE have been extensively studied in these conditions, their application in migraine management remains limited. Our recent review highlighted a significant gap in the literature, revealing that TC approaches are rarely implemented in migraine populations despite their potential benefits [46].

The higher prevalence of migraine among women is well documented in the literature, with epidemiology studies reporting an approximately female:male ratio of 3:1. For instance, a meta-analysis by Lemmens et al. [16] reported that 88% of included participants were female, while La Touche et al. [47] observed a female representation of 92% in their sample. Consistent with

TABLE 2 | Changes in body weight and BMI between baseline (T0) and postintervention (T1).

	Time	Mean	Median	SD	Q1	Q3
Weight	T0	62.21	62.00	10.73	54.50	65.00
	T1	61.37	60.00	11.11	54.00	64.50
BMI	T0	23.44	23.37	3.88	21.03	25.39
	T1	23.01	22.32	4.00	20.83	24.52

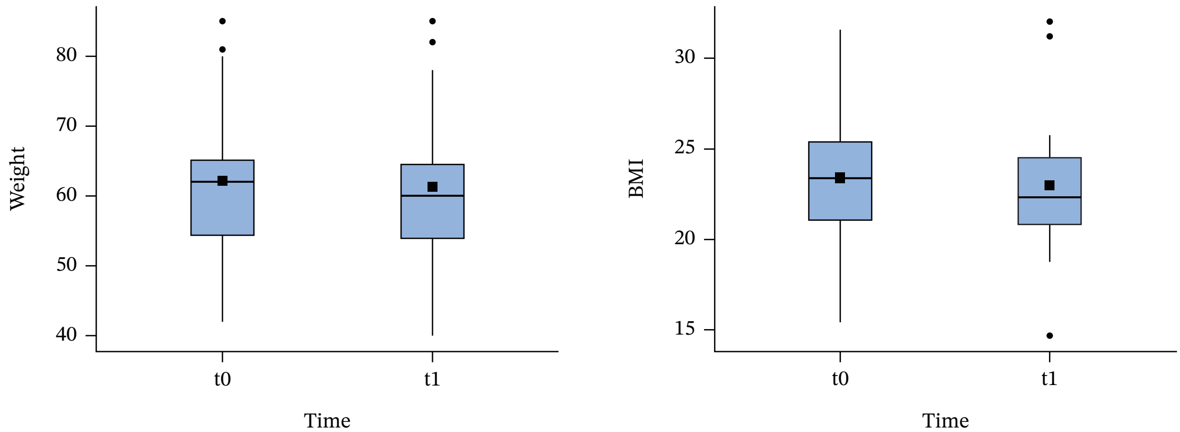

FIGURE 2 | Box plots of body weight and body mass index (BMI) at baseline (T0) and postintervention (T1). The light blue boxes represent the interquartile range (IQR: Q1–Q3), the horizontal black line within each box indicates the median, and the black square denotes the mean value. Black dots represent outliers.

TABLE 3 | Changes in migraine characteristics between baseline (T0) and postintervention (T1).

	Time	Mean	Median	SD	Q1	Q3	*p* value
Headache days	T0	13.50	11.50	7.29	7.75	18.75	0.012
	T1	11.40	8.50	6.88	6.00	15.50	
Mean intensity	T0	5.86	6.00	1.41	5.00	7.00	0.570
	T1	5.50	5.88	2.14	4.00	7.00	

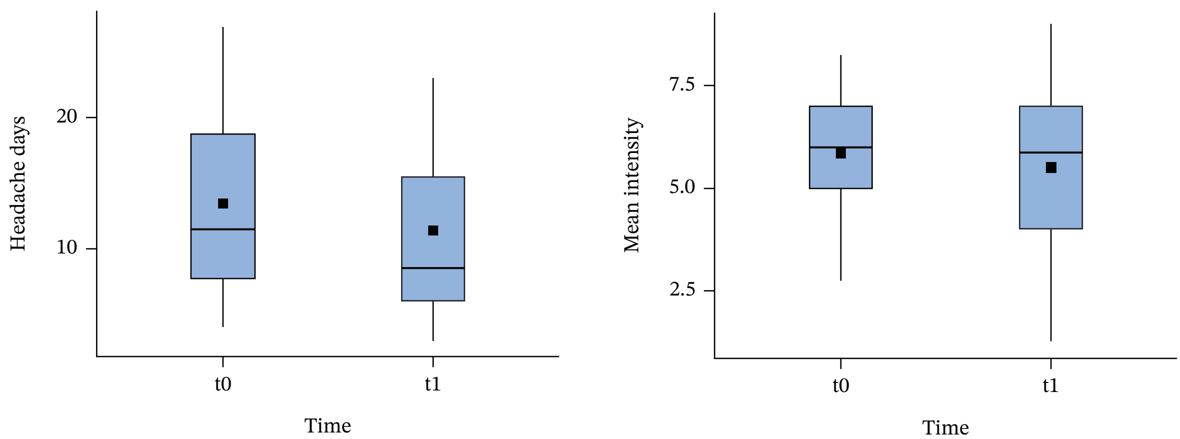

FIGURE 3 | Box plots of migraine features at T0 and T1. The light blue boxes represent the interquartile range (Q1–Q3), the black horizontal line indicates the median, and the black square denotes the mean.

these findings, our study also demonstrated a predominance of women, with 90% of participants being female. This further supports the notion that migraine disproportionately affects females and highlights the importance of gender-sensitive approaches in research and clinical interventions for this population.

Aerobic training, which can be defined as a "structured activity involving the use of large muscle groups in a rhythmic manner for extended periods, such as walking, stepping, running, swimming, cycling, and rowing" [48], plays a crucial role in the prevention and management of various chronic conditions, including migraine [49–51]. Is et al. evaluated the effectiveness of a 12-week aerobic exercise program compared to cervical exercises for migraine treatment [52]. Fifty-one patients were divided into two groups: One performed aerobic exercise, while the other carried out cervical exercises. Both groups showed statistically significant improvements in migraine parameters, with the aerobic exercise group demonstrating a significantly lower frequency of attacks compared to the cervical exercise group. In line with the scientific literature, a reduction of more than one migraine day per month is generally considered clinically meaningful [53]. Our study observed a statistically significant decrease in migraine frequency, supporting the hypothesis that a supervised aerobic training program delivered through TC can effectively reduce the number of migraine attacks. Aerobic training is known to exert multiple physiological effects that may contribute to migraine management, including the modulation of systemic inflammation [54], regulation of

TABLE 4 | Changes in secondary outcomes between baseline (T0) and postintervention (T1).

	Time	Mean	Median	SD	Q1	Q3
HIT-6	T0	60.11	61.00	6.09	59.00	63.50
	T1	60.21	61.00	7.70	56.50	65.50
BDI-II	T0	10.58	10.00	7.26	6.00	15.00
	T1	11.37	11.00	8.05	5.50	15.50
HADS-A	T0	7.68	7.00	3.99	5.50	10.50
	T1	7.79	6.00	4.63	5.00	9.00
HADS-D	T0	4.74	5.00	2.60	3.00	6.50
	T1	4.84	4.00	3.11	2.50	6.50
PSQI	T0	7.26	7.00	4.03	4.50	8.00
	T1	8.05	8.00	3.75	5.50	9.50
Role function-restrictive (RR)	T0	55.64	60.00	16.48	52.86	61.43
	T1	51.88	57.14	23.53	40.00	64.29
Role function-preventive (RP)	T0	56.84	60.00	18.94	50.00	60.00
	T1	55.53	55.00	25.49	37.50	77.50
Emotional function (EF)	T0	70.53	80.00	28.83	53.33	93.33
	T1	64.91	66.67	30.54	50.00	90.00
MSQ total average	T0	61.00	64.76	20.19	54.60	71.59
	T1	57.44	60.00	24.86	42.78	76.83

TABLE 5 | Changes in physical activity parameters between baseline (T0) and postintervention (T1).

	Time	Mean	Median	SD	Q1	Q3	*p* value
MET vigorous	T0	513.68	0.00	1050.99	0.00	720.00	0.474
	T1	1358.32	240.00	3351.89	0.00	840.00	
MET moderate	T0	2185.26	360.00	5673.18	0.00	1800.00	0.495
	T1	2367.37	720.00	4198.38	400.00	1880.00	
MET walking	T0	1422.45	594.00	3366.81	225.00	975.00	0.444
	T1	1673.76	600.00	2689.40	383.25	1282.50	
MET tot	T0	4121.39	1230.00	8961.93	987.50	3100.00	0.275
	T1	5399.45	2750.00	5968.58	1190.00	7423.25	

neurotransmitters [55], and improved cerebral vascularization [56]. These mechanisms could explain the observed reduction in headache frequency, suggesting that regular TC–aerobic training may play a role as a valuable nonpharmacological strategy in migraine management. Conversely, no statistically significant changes were found in headache intensity. This outcome may be explained by the subjective nature of pain intensity, which is influenced by multiple factors such as stress, sleep quality, and concurrent therapies [26]. Thus, while aerobic exercise appears to reduce the likelihood of migraine attacks, it may have a limited impact on the severity of pain once an attack occurs.

No significant changes were observed in QoL scores, despite a slight trend of reduction in the emotional functioning field. It is then possible that larger samples may highlight a positive effect of TC exercise on some aspects of QoL. In line with these findings, sleep quality, migraine-related disability, or psychological measures did not change significantly. The absence of change in depression scores may be due to the participants' baseline scores being within normal ranges, which limits the sensitivity of the assessment tools to detect changes in nondepressed individuals [57].

Furthermore, no statistically significant change was detected in overall PA levels, likely reflecting the already high baseline activity of the participant group. Despite a slight reduction, considering BMI in the multivariate analysis, no significant changes were observed following the 12-week aerobic program. There is a known

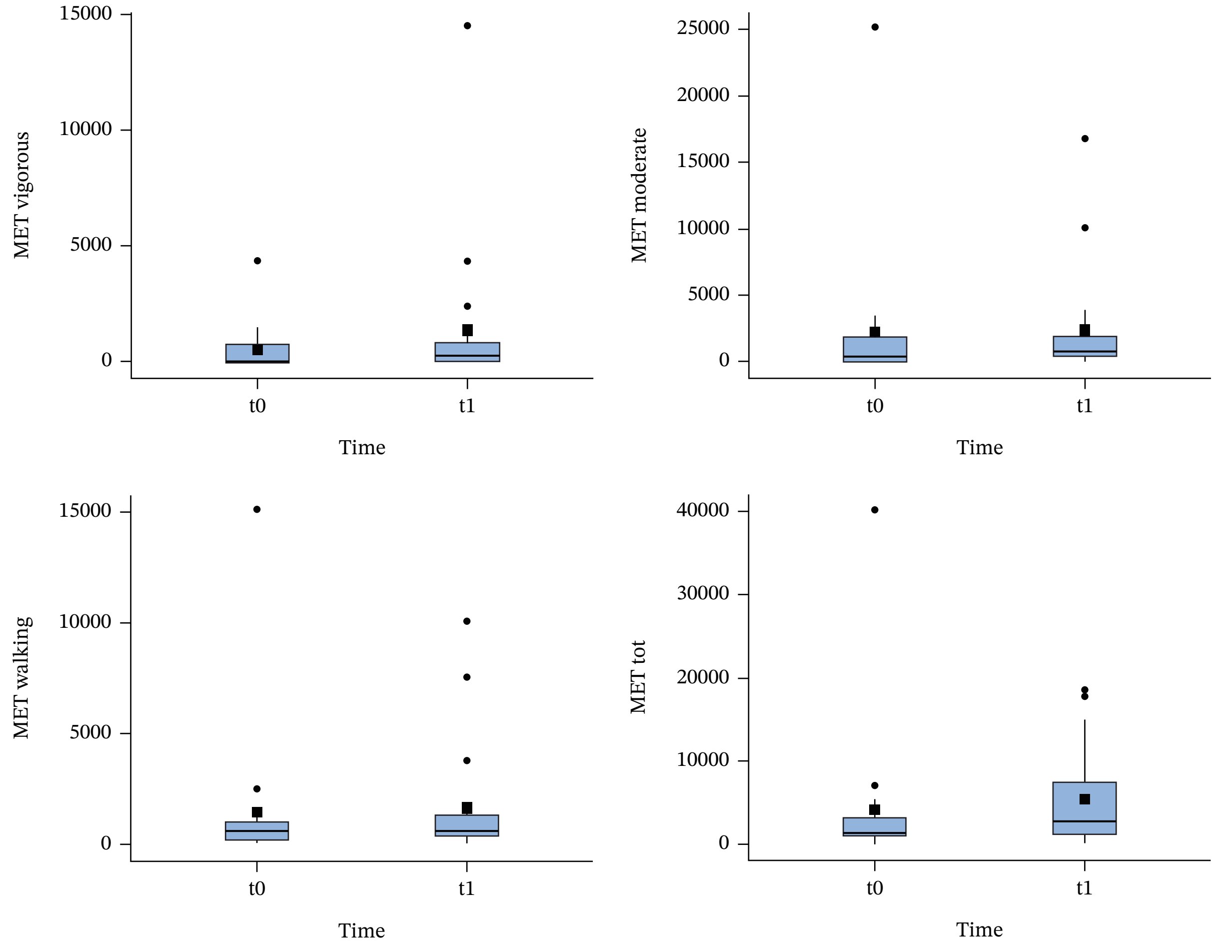

FIGURE 4 | Physical activity parameter box plots. The light blue rectangle represents the interquartile range (Q1–Q3), the black horizontal line indicates the median value, the black square denotes the mean value, and the black dots represent outliers.

association between obesity and migraine severity so that even modest reductions in BMI may indirectly contribute to symptom improvement in this population [58]. A recent meta-analysis identified an association between BMI and headache, with Martami et al. suggesting a nonlinear relationship between these variables [58]. Specifically, both underweight and obese individuals were found to have an increased risk of migraine, highlighting the importance of weight management in headache prevention. This association is further supported by Kristoffersen et al., who reported a relationship between migraine and both general obesity and abdominal obesity [59]. Importantly, this association was more pronounced in individuals under 50 years of age and was observed in patients with migraine both with and without aura. Moreover, obesity (BMI ≥ 30) is among the negative predictive factors of response to the recent (and usually effective) anti-CGRP monoclonal antibody (mAb) preventatives [6].

4.1 | Strengths and Limitations

The main strength of this pilot study is the excellent adherence to the training program, with 100% of participants completing the 12-week intervention. This high rate highlights the feasibility and acceptability of a TC–aerobic training program. Additional strengths include the absence of adverse events or injuries during the intervention period, underscoring the safety of the proposed program. The flexibility and accessibility of the training program, delivered remotely via TC and performed in a GE, further enhanced participant engagement and compliance. Moreover, the intervention was designed and supervised by professionals in sports and exercise science, in collaboration with neurologists, ensuring both scientific validity and clinical relevance. Despite these strengths, the study presents several limitations. As a pilot investigation, the small sample size limits the generalizability of the findings. While the predominance of female participants aligns with the known epidemiology of migraine, the limited number of male participants constrains the applicability of results across genders. The absence of a control group limits definitive attribution of observed effects to the intervention alone. Despite the use of headache diaries increasing the accuracy of headache recordings, some questionnaires, such as HIT-6, ask the patients to recall information regarding the previous 4 weeks, so they may include a certain amount of recollection bias. Additionally, the 12-week duration may have been insufficient to detect longer term outcomes or sustainability of benefits, such as those linked to QoL and psychological state. The relatively high baseline PA levels of participants may have limited the extent of observable changes in PA-related outcomes. Finally, the 100% adherence observed may reflect a selection bias, as patients not inclined or unable to engage in regular PA were likely not included, and therefore, the results may primarily represent individuals who are motivated and capable of adhering to an exercise program.

4.2 | Future Directions

Future developments of this pilot study should include expanding the sample size to improve statistical power and generalizability, with a particular focus on increasing male representation to better reflect the broader population affected by migraine. Incorporating a control group would strengthen the methodological rigor and allow for more robust comparisons. Additionally, the inclusion of further outcome measures, such as headache episode duration, number of days with acute medication intake, and heart rate variability, could provide a more comprehensive understanding of the intervention's impact. Lastly, the integration of wearable devices, such as smartwatches, could enhance the personalization and monitoring of the training program, offering real-time feedback to telecoaches and facilitating more precise modifications based on participants' physiological responses and adherence.

5 | Conclusions

The findings of this pilot study suggest that a 12-week aerobic training program, performed in a GE and supported by TC, may be effective in reducing the frequency of migraine attacks in individuals with migraine. The intervention demonstrated to be feasible, safe, and well tolerated, with satisfactory adherence rates, supporting its potential as a nonpharmacological approach for migraine management. However, further research involving larger and more heterogeneous samples, as well as more rigorous study designs, is warranted to confirm these preliminary results and improve their generalizability.

Author Contributions

Ignazio Leale: methodology, investigation, and writing—original draft. Angelo Torrente: formal analysis, investigation, and writing—original draft. Vincenzo Di Stefano: conceptualization, methodology, and writing—review and editing. Francesco Cutaia: investigation and resources. Salvatore Maria Lima: investigation and resources. Paolo Alonge: investigation and resources. Cecilia Camarda: writing—review and editing. Filippo Brighina: conceptualization and supervision. Giuseppe Battaglia: conceptualization, writing (review and editing), and supervision.

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Ethics Statement

The study was approved by the Ethics Committee Palermo 1 of the University Hospital "Policlinico di Palermo" (approval number: 04/2023), and it was conducted in accordance with the principles outlined in the Declaration of Helsinki.

Consent

All participants provided written informed consent prior to enrolment.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

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