



RESEARCH ARTICLE

Effects of global postural reeducation on postural control, dynamic balance, and ankle range of motion in patients with hallux abducto valgus. A randomized controlled trial

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Abstract

Hallux abducto valgus (HAV) is a common musculoskeletal disorder that has been addressed surgically. Nevertheless, the manual therapy approach may play an important role in the management of this condition. The present study aimed to determine the effectiveness of global postural reeducation (GPR) in subjects with symptomatic mild to moderate HAV in static postural control, dynamic stability, and ankle dorsiflexion range of motion (DFROM). A total of 80 patients with mild to moderate symptomatic HAV were allocated to the intervention group (GPR) or control group (CG) (no treatment) for 8 weeks. Outcome measures were assessed at baseline at 4 and 8 weeks including static postural control (Romberg test), dynamic balance (Star Excursion Balance Test [SEBT]), and ankle DFROM (Weight-Bearing Lunge Test [WBLT]). No improvements were observed at 4 weeks, but there were improvements at 8 weeks in: static postural control mediolateral displacement (X) of center of pressure (CoP) in both eyes open (EO) and eyes closed (EC): XEO ($t(36) = 2.892$, $p = .006$, $d = 0.67$); XEC ($t(68) = 2.280$, $p = .026$, $d = 0.54$); and velocity (V) of CoP displacement: VEO ($t(68) = 2.380$, $p = .020$, $d = 0.57$); VEC ($t(36) = 2.057$, $p = .047$, $d = 0.37$). It were also improvements in: WBLT ($t(36) = -2.869$, $p = .007$, $d = 0.54$) and SEBT at three directions (anterior, ANT; posteromedial, PM; and posterolateral, PL): SEBT.ANT ($t(36) = -2.292$, $p = .028$, $d = 0.23$); SEBT.PM ($t(36) = -4.075$, $p < .001$, $d = 0.43$); SEBT.PL ($t(62) = -3.506$, $p = .001$, $d = 0.34$). The present study showed that GPR compared to the CG might be effective in enhancing ankle function including postural control, dynamic balance, and DFROM.

KEYWORDS

dynamic balance, global postural reeducation, hallux abducto valgus, postural control, range of motion

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1 | INTRODUCTION

Hallux abducto valgus (HAV) is defined as a static subluxation of the first metatarsophalangeal joint with lateral deviation of the great toe and medial deviation of the first metatarsal.¹ It is the most frequent foot pathology with a prevalence of 30% in women and 13% in men and it tends to increase with age.¹ HAV exists when there is an angle of $\geq 15^\circ$ between the longitudinal bisection of the first proximal phalangeal bone and the first metatarsal.² Severity can be classified in degrees or Manchester Scale (MS) grades: $<15^\circ$ no HAV deformity (MS Grade 1); $15\text{--}20^\circ$ mild HAV deformity (MS Grade 2); $21\text{--}39^\circ$ moderate HAV deformity (MS Grade 3); $\geq 40^\circ$ severe HAV deformity (MS Grade 4).³

The etiology is unknown, but it has been related to the pronated foot, metatarsophalangeal osteoarthritis, intrinsic foot musculature strength deficits,⁴ genetics⁵ big toe pain,^{4,5} and the use of some kind of shoes including heels or narrow shoes.⁶ HAV may lead to pain,⁷ postural control alteration,⁸ increased risk of falls,^{7,9} and associated risk of foot injury due to plantar pressure alteration resulting from the altered morphology^{7,8,10} and biomechanics.⁷

Foot joints, muscles, and plantar mechanoreceptors are very important in feedback and feedforward mechanisms so, if they are altered, proprioception and postural control could be negatively affected.^{8,10} If there are alterations of gait and plantar pressure peaks, load distribution of the foot can be modified, and this is related to metatarsalgia, HAV, or risk of falls.^{7,9} When HAV deformity exists, postural stability decreases, specially mediolateral stability⁸ which could also be related to musculature strength deficits.^{4,11,12}

Regarding the therapeutic approach of patients with HAV, the most common treatment is surgery.¹³ Current literature includes joint mobilizations, exercise, ice, and orthopedics implements that involve toes separator and night splints at the early stages of the pathology but until recently this is the first study addressing the effectiveness of manual therapy approach on this pathology.^{13,14} global postural reeducation (GPR) method consists of a combination of manual therapy and therapeutic exercise in which a pretension of the targeted myofascial chain is maintained, while the participant holds a specific treatment posture isometrically.^{15,16} GPR is effective in the management of several musculoskeletal disorders including temporomandibular dysfunction, urinary incontinence, and spine injuries.^{16,17} There was no previous research addressing the effectiveness of this method in subjects with HAV, but it may be helpful for the conservative management of this condition taking into account the aforementioned literature.

Therefore, the present study aimed to determine the effectiveness of GPR in subjects with symptomatic mild to moderate HAV in static postural control, dynamic stability, and ankle dorsiflexion range of motion (DFROM).

2 | METHODS

2.1 | Design

This study was a Randomized Controlled Trial, with an experimental group (EG) consisted of GPR and a CG that received no intervention. Patients were told to continue with their usual daily life activities. The study (NCT04468555) was approved by the Human Ethics Committee of the University of Jaén and conducted following the Declaration of Helsinki, good clinical practices, and applicable laws and regulations and meets the CONSORT guidelines standards.¹² Informed consent was obtained for all participants who accepted to be enrolled in the study. The sample was obtained by volunteers via social networks and posters in different University and Hospital locations.

2.2 | Outcome measures

The assessment was performed at baseline and after 4 and 8 weeks by an independent investigator. Sociodemographic and baseline data are described in Table 1.

2.2.1 | Static postural control

Stabilometric parameters were measured on a bipodal stance with a stabilometric platform of pressure resistive sensors (Sensor Medica). The Romberg test was performed in eyes open (EO) and eyes closed (EC) conditions. In this test, participants should be in a barefoot bipodal stance with a 2 cm separation between heels and an angle of 30° between the feet.¹⁸ Each measure consisted of 30 s of holding the stand position, following by 1 min of rest between EO and EC tests and a sampling frequency of 40 Hz.¹⁹ The assessed parameters were related to the center of pressure (CoP) in both EO and EC conditions: mediolateral (X) and anteroposterior (Y) mean displacements of the CoP (mm), and velocity of CoP movement (v , in mm/s).¹⁹ Smaller scores indicate better postural stability.²⁰

2.2.2 | Dynamic balance

was examined with the Star Excursion Balance Test (SEBT). It was assessed the three reach directions of the SEBT simplified version because it has been reported to be a reliable tool for measuring dynamic balance in people with lower-limb dysfunction with excellent test-retest reliability.²¹ The test is performed while standing on a barefoot single-leg position with the affected limb positioned in the middle of the SEBT grid while the participant reaches the longest distance possible for all the three directions as described by Gribble et al.²¹ Low scores are related to an increased risk of injury in the lower limb.²¹ This test has been widely employed for monitoring the effectiveness of different physiotherapy approaches in dynamic balance.^{21,22}

2.2.3 | Ankle DFROM

The Ankle DFROM was assessed with the Weight-Bearing Lunge Test (WBLT), which involves the participant standing on a tandem stance while performing a forward lunge.²³ During this task, the involved foot remained firmly planted on the ground as the tibia progressed over the talus into maximum ankle DFROM and the maximum distance from the great toe to the wall is measured.²³ While performing the WBLT, the clinician controlled the position of the feet, the knees, and the pelvis to check the correct execution.²³ It has been reported that WBLT is a valid test and has good reliability and reproducibility, being widely employed for monitoring change over time in manual therapy, including plantar

massage and joint mobilization for subjects with CAI and sport-based intervention.^{24,25} Previous research has shown that WBLT is correlated with dynamic postural control measures.²⁶

2.3 | Participants and allocation

Participants were allocated by an independent investigator who used a random number generator and sealed the treatment sequence in opaque envelopes that were opened before performing the first intervention. As there is no consensus for eligibility criteria in manual therapy approaches for HAV, our participation eligibility criteria were

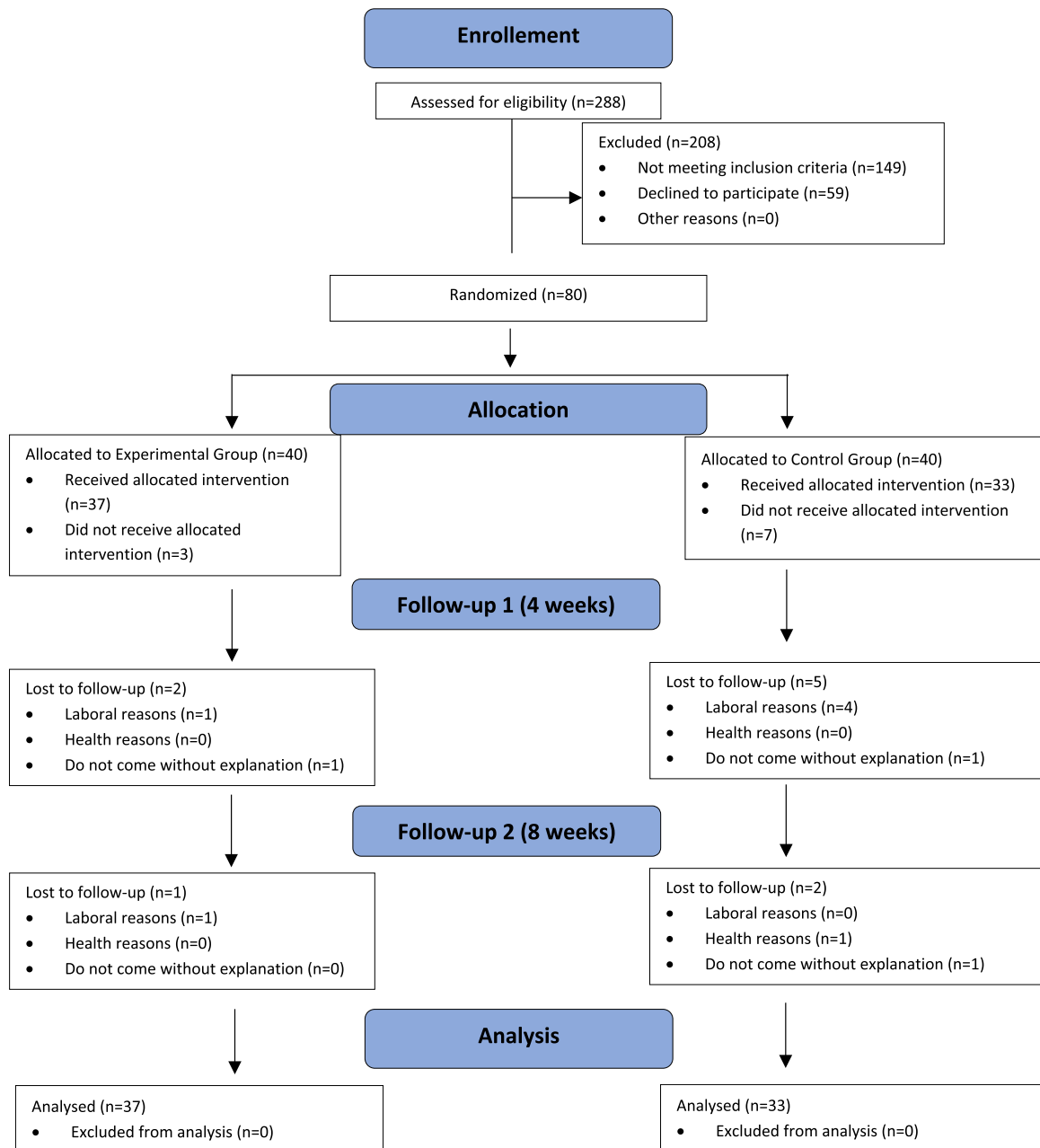


FIGURE 1 Flow diagram according to CONSORT.²⁸ [Color figure can be viewed at wileyonlinelibrary.com]

consistent with Abdalbary et al.,¹⁴ and du Plessis et al.,²⁷ Inclusion criteria for participants were (A) having mild to moderate HAV deformity evaluated with MS;⁶ (B) 18–65 years; (C) painful HAV. If there were bilateral HAV, we included in the study the most symptomatic and/or the one comprised between mild to moderate.^{14,27} Exclusion criteria for participants included (A) surgeries in the lower limbs; (B) pathologic foot deformities not related to HAV; (C) to have been receiving physiotherapy treatment for HAV; (D) to suffer systemic diseases as deposit sickness or rheumatoid arthritis; (E) severe osteoarthritis; (F) to suffer any disease that affects the sensory-motor function of the foot different from the HAV; (G) to suffer any fracture or disease that was still affecting the foot; (H) patients with anti-inflammatory drugs where manual therapy was contraindicated.^{14,27}

After participant screening, those who accept to take part in the study were randomly assigned to the control (no treatment) or experimental (GPR) group. Participants in both groups were instructed for continuing with their habitual daily life activities. Participant demographic information can be found in Table 1.

2.4 | Intervention

Individuals allocated to CG received no intervention, and those assigned to EG received three sessions based on the GPR methodology. Figure 1 shows the flow diagram according to the Consort statement.¹²

Participants allocated to the intervention group received a treatment consisted of a GPR approach divided into 3 sessions and performed with a frequency of 1 session per week for 3 weeks. The sessions were performed individually, with an approximate duration of 40 min and all of them were assessed by the same physiotherapist. In the GPR methodology, there are several postures described for performing the treatment in which the subject has to actively participate.^{15,16} Each session was divided into 5 parts, according to the methodology, without rest, progressing in the posture.¹⁵ In this progression, postural demands increased during task execution with greater activation of intrinsic foot muscles.²⁹ A more detailed description can be found in Table 2 (Figure 2).

TABLE 1 Baseline characteristics

	Total (n = 70)	CG (n = 33)	EG (n = 37)	p value
Age	45.83 ± 11.93	43.52 ± 12.90	47.89 ± 10.76	.217
Gender				
Male	4 (5.71)	2 (50)	2 (50)	.906
Female	66 (94.29)	31 (47)	35 (53)	
Foot size (EU)	38.44 ± 1.66	38.15 ± 1.46	38.70 ± 1.79	.166
HAV foot				
Left	38 (54.29)	18 (47.40)	20 (52.60)	.967
Right	32 (45.71)	15 (46.90)	17 (53.10)	
Weight (Kg)	67.26 ± 11.07	66.87 ± 10.85	67.60 ± 11.40	.784
Height (cm)	1.61 ± 0.07	1.62 ± 0.06	1.61 ± 0.07	.494
BMI	25.82 ± 4.28	25.49 ± 4.27	26.10 ± 4.32	.553
XEO	0.55 ± 0.09	0.54 ± 0.08	0.57 ± 0.10	.199
XEC	0.60 ± 0.10	0.59 ± 0.10	0.60 ± 0.10	.199
YEO	0.36 ± 0.08	0.36 ± 0.09	0.35 ± 0.07	.813
YEC	0.43 ± 0.13	0.45 ± 0.16	0.41 ± 0.10	.188
VEO	14.50 ± 2.37	14.42 ± 2.47	14.57 ± 2.31	.782
VEC	14.87 ± 2.46	14.46 ± 2.51	15.24 ± 2.38	.183
WBLT	6.10 ± 2.49	6.53 ± 2.71	5.73 ± 2.25	.185
SEBT.ANT	62.54 ± 7.54	62.06 ± 7.76	62.96 ± 7.42	.620
SEBT.PM	60.96 ± 11.28	60.02 ± 11.59	61.79 ± 11.08	.515
SEBT.PL	59.33 ± 12.48	58.71 ± 12.55	59.89 ± 12.57	.695

Note: Quantitative variables are presented as the mean ± SD. XEO: mediolateral oscillations of the CoP in OE condition; XEC: mediolateral oscillations of the CoP in EC condition; YEO: anteroposterior oscillations of the CoP in EO condition; YEC: anteroposterior oscillations of the CoP in EC condition; VEO: displacement velocity of the CoP in EO condition; VEC: displacement velocity of the CoP in EC condition; WBLT: weight-bearing lunge test; SEBT.ANT: star excursion balance test anterior direction; SEBT.PM: star excursion balance test posteromedial direction; SEBT.PL: star excursion balance test posterolateral direction.

2.5 | Statistical analysis

Statistical analyses were performed with SPSS statistical software, V17.0 (SPSS, Inc.). Each variable of interest was calculated: mean values, SDs, and the number of cases. The student's *t* test was used for independent samples and the statistical Chi-square test for analyzing the differences between both groups. Demographic data and baseline results are showed in Table 1, with no statistical differences (Figure 3).

A mixed analysis of variance was employed for assessing differences between and within groups. Independent variables were CG and EG, so CG versus EG was the between-group factor, while the within-group factor was time measurement (4 and 8 weeks). Dependent variables were stabilometric measurements under both EO and EC conditions; SEBT measurements in different directions; and WBLT for ankle DFROM. Separate analyses for the dependent variables were performed for examining possible interactions between treatment and measurement time. A *p* value of <.05 was considered statistically significant. Intergroup effect sizes (ES) were calculated using Cohen's *d* and categorized as small (*d* = 0.2), medium

(*d* = 0.5), and large (*d* = 0.8) according to Cohen's benchmarks.³⁰

Table 3 shows the results of all outcome measures.

3 | RESULTS

The results showed no significant main effects in XEO, XEC, YEO, YEC, VEO, VEC, WBLT, SEBT.ANT, SEBT.PM and SEBT.PL on Time, Group, and Group by Time at 4 weeks.

However, results on XEO and XEC showed improvements at 8 weeks on EG with medium ES: $t(36) = 2.892$, $p = .006$, $d = 0.67$; and small ES: $t(36) = 2.349$, $p = .024$, $d = 0.42$, respectively. Comparison between groups on XEC showed improvements on EG after intervention with medium ES: $t(68) = 2.280$, $p = .026$, $d = 0.54$ (Table 3).

At 8 weeks, results in YEO and YEC showed no significant effects on Group and Group by Time interaction. Significant effects on Time were found in YEO variable, but not in YEC.

There were improvements in VEO and VEC on EG with small ES: $t(36) = 2.178$, $p = .036$, $d = 0.38$; and $t(36) = 2.057$, $p = 0.047$, $d = 0.37$,

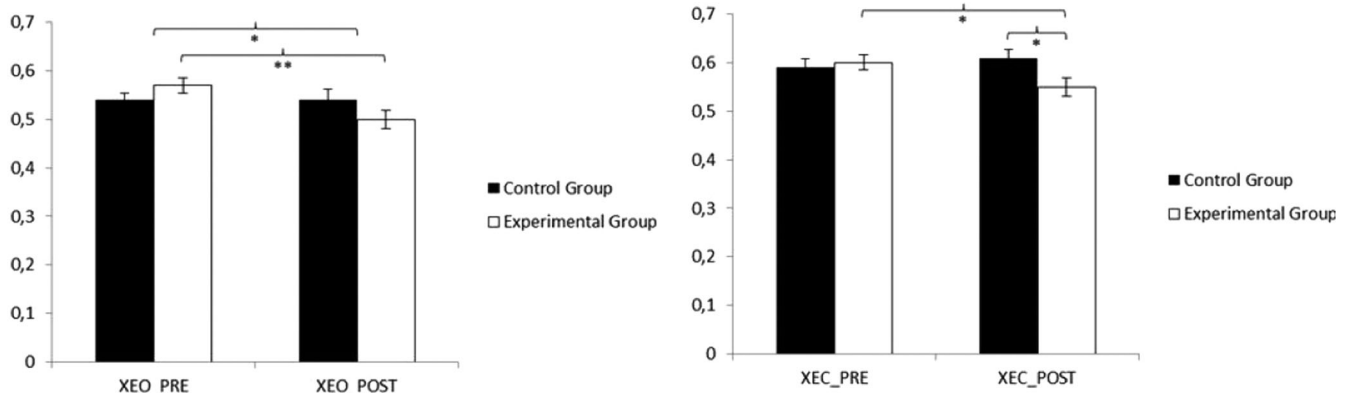


FIGURE 2 Between-group and within-group comparison of XEO and XEC scores. XEO: mediolateral displacements of the centre of pressure with eyes open; XEC: mediolateral displacements of the centre of pressure with eyes closed. * $p < .05$; ** $p < .01$

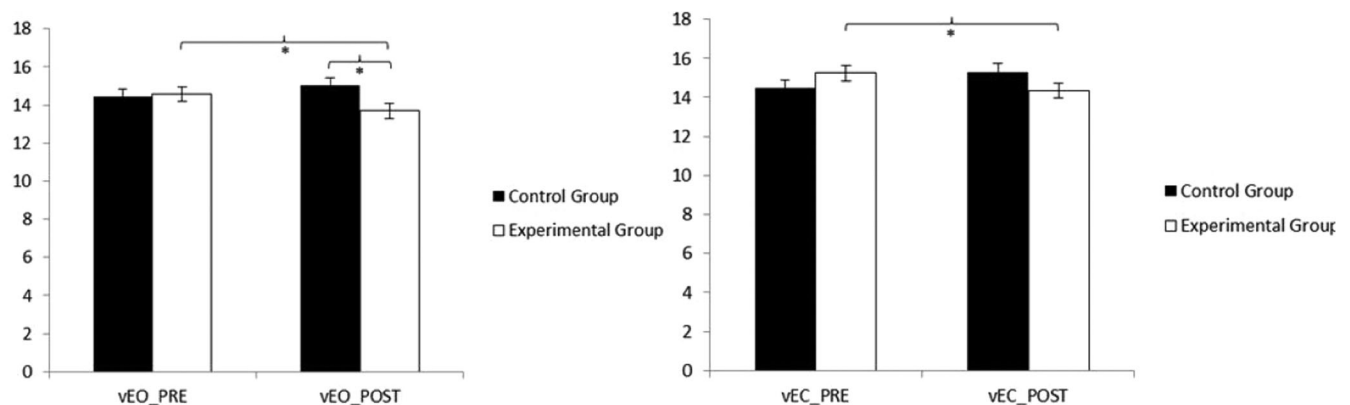


FIGURE 3 Between-group and within-group comparison of vEO and vEC scores. vEO: mean speed of displacement of the pressure center with open eyes; vEC: mean speed of displacement of the pressure center with eyes closed. * $p < .05$

TABLE 2 Treatment description



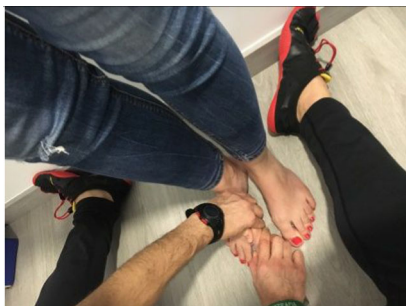
1. Supine position progressing to knee extension and neutral position of the coxofemoral joint, as the feet maintained a plantarflexion position (also known as "ground frog posture"). We performed this posture during 20', focusing on the manual alignment of the first ray and foot joints. At the same time, there were performed isometric contractions of the intrinsic and extrinsic musculature of the elected foot.



2. Supine position progressing to knee extension and coxofemoral joint flexion as the foot maintained a dorsiflexion position (also known as "airborne frog posture"). The original posture described for Souchard⁴⁹ is performed with both feet, but we modified it because the original technique does not provide additional benefits in this investigation. We performed this posture during 10', focusing on the manual alignment of the first ray and foot joints. At the same time, there were performed isometric contractions of the intrinsic and extrinsic musculature of the elected foot. We also asked for voluntary abduction of the first proximal phalanx.



3. Bipodal stance position with back support on the wall, asking for elevation of the medial longitudinal arch, isometric contraction of the intrinsic and extrinsic foot musculature and voluntary abduction of the first proximal phalanx. The physiotherapist performed a manual alignment of the first ray. We performed this posture during 2'30". This is a static task for integrate the results obtained after the contractions in supine position in the CNS.



4. Bipodal stance position without back support on the wall, asking for elevation of the medial longitudinal arch, isometric contraction of the intrinsic and extrinsic foot musculature and voluntary abduction of the first proximal phalanx. The physiotherapist performed a manual alignment of the first ray. We performed this posture during 2'30". This is a static task for integrate the results obtained after the contractions in supine position in the CNS.



5. Walk maintaining the alignment of the first ray, an elevated medial longitudinal arch and dorsiflexion of the first proximal metatarsophalangeal joint. We performed this task during 5'. This is a dynamic task for integrate the results obtained after the previous work in the CNS.

Abbreviation: CNS, central nervous system.

respectively. Comparison between groups in VEO showed improvements on EG with medium ES: $t(68) = 2.380, p = .020, d = 0.57$.

Results showed improvements in WBLT on EG after intervention at 8 weeks with medium ES: $t(36) = -2.869, p = .007, d = 0.54$.

There were improvements in SEBT.ANT and SEBT.PL at 8 weeks with small ES: $t(36) = -2.445, p = .019, d = 0.26$; and $t(36) = -3.581, p < .001, d = 0.39$, respectively. Table 3 shows outcome measures.

Results in SEBT.PM at 8 weeks showed improvements on EG with large ES: $t(36) = -11.275, p < .001, d = 1.04$.

4 | DISCUSSION

The obtained results showed that 8 weeks after 3 GPR sessions, participants from EG improved their static postural control in both EO and EC conditions, dynamic balance, and ankle DFROM. Nevertheless, there were no improvements after 4 weeks. A plausible explanation could be more time is needed for integration of the received stimulus by the central nervous system (CNS). The intervention for HAV consisted of a multimodal intervention including manual therapy and muscular contractions combined with tissue and joints mobilization following the GPR principles. Until recently, this is the first investigation addressing the effectiveness of manual therapy methods in DFROM, postural control, and dynamic balance in patients with HAV.

The sole is involved in CNS processes including postural control and balance due to the high density of cutaneous mechanoreceptors that influence proprioceptive and exteroceptive information of the body position and the support state.¹⁰ The function of mechanoreceptors could change due to biomechanical alterations in HAV conditions.^{7,8,10} This may lead to poor postural control⁸ decreased balance,¹⁰ lower physical activity,²⁸ risk of falls^{7,9,28} risk of injury,^{16,28} and limited mobility and ambulation.²⁸ Literature also supports that plantar, joint, and muscular receptors are involved in feedback and feedforward mechanisms and it is possible to induce changes in balance and ankle DFROM in people with CAI.^{24,25,31} The foot core

musculature is responsible for the stabilization and oscillations of the CoP¹¹ and, in presence of muscle weakness or decreased activation, postural control and dynamic balance could be negatively affected, which could be related to an increased risk of falls.^{9,29,32} Conservative methods that focus on improving dynamic balance, postural control, and ankle DFROM could decrease the risk of injuries.^{21,22,24,33}

4.1 | Manual therapy in HAV and postural control

Decreased postural control is related to several musculoskeletal conditions such as HAV,⁴ ankle sprains,³⁴ or ACL injuries.³⁵ In presence of HAV, mediolateral oscillations are affected and the risk of falls could be increased.^{4,8} Anteroposterior oscillations did not improve in our study, this finding may be explained taking into account that it has been reported that anteroposterior oscillations are not altered in presence of HAV.^{4,8} However, our results have shown that GPR treatment improves mediolateral parameters in bipodal stance and both EO and EC conditions with moderate and small ES ($d = 0.67$ and $d = 0.42$, respectively) after 8 weeks. These improvements in mediolateral oscillations could be present due to neurophysiological mechanisms underlying manual therapy, which stimulates cutaneous, joint, and muscular receptors, in addition to muscle activation, that has demonstrated improvements in postural control and dynamic balance.^{10,24,25,36-38} These positive outcomes could be related to a decrease in the risk of falls^{4,7-9} and injuries.^{34,35}

Akaras et al.,²⁰ did not found differences between non-taping conditions, athletic tape, and Mulligan tape for static postural control in anteroposterior oscillations, which agree with our results and previous literature.^{4,8} Other investigations found no improvements neither in mediolateral oscillations nor sway velocity in taping conditions for HAV,^{20,39} in contrast to our results, suggesting that GPR could be superior to taping intervention. A plausible explanation of these results could be the combination of active muscle activation of the patient and manual therapy application. Previous studies showed improvements in postural control of people with CAI when performed plantar massage,³³ which could be related to the

TABLE 3 Outcome measures

	4 Weeks				8 Weeks				Time						
	CG (n = 33)		EG (n = 37)		CG (n = 33)		EG (n = 37)		CG (n = 33)		EG (n = 37)		Time		
	Pre	Post (4 weeks)	Post (8 weeks)	Post (8 weeks)	Pre	Post (4 weeks)	Post (8 semanas)	Post (8 semanas)	F(1,68)	p value	η^2	F(1,68)	p value	η^2	
XEO	0.54 ± 0.08	0.55 ± 0.11	0.54 ± 0.12	0.54 ± 0.12	0.57 ± 0.10	0.52 ± 0.12	0.50 ± 0.11	0.50 ± 0.11	3.027	.086	0.043	0.898	.347	0.013	
XEC	0.59 ± 0.10	0.61 ± 0.12	0.61 ± 0.10	0.61 ± 0.10	0.60 ± 0.10	0.58 ± 0.96	0.55 ± 0.12	0.55 ± 0.12	0.710	.402	0.010	0.004	.948	0.001	
YEO	0.36 ± 0.09	0.38 ± 0.91	0.40 ± 0.09	0.40 ± 0.09	0.35 ± 0.07	0.36 ± 0.11	0.38 ± 0.10	0.38 ± 0.10	0.941	.335	0.014	0.301	.585	0.004	
YEC	0.45 ± 0.16	0.45 ± 0.12	0.44 ± 0.10	0.44 ± 0.10	0.41 ± 0.10	0.43 ± 0.14	0.43 ± 0.12	0.43 ± 0.12	1.535	.220	0.022	0.412	.523	0.06	
VEO	14.42 ± 2.47	13.74 ± 2.10	15.01 ± 2.33	15.01 ± 2.33	14.57 ± 2.31	13.34 ± 2.21	13.68 ± 2.34	13.68 ± 2.34	0.069	.794	0.001	8.889	.004	0.116	
VEC	14.46 ± 2.51	15.06 ± 2.21	15.27 ± 2.66	15.27 ± 2.66	15.24 ± 2.38	14.53 ± 2.12	14.36 ± 2.36	14.36 ± 2.36	0.089	.767	0.001	0.021	.886	0.001	
WBLT	6.53 ± 2.71	7.05 ± 2.70	6.48 ± 2.16	6.48 ± 2.16	5.73 ± 2.25	6.28 ± 2.40	7.08 ± 2.71	7.08 ± 2.71	2.270	.137	0.032	3.184	.079	0.045	
SEBT.ANT	62.06 ± 7.76	62.90 ± 8.61	61.28 ± 9.65	61.28 ± 9.65	62.96 ± 7.42	62.39 ± 6.30	64.89 ± 7.53	64.89 ± 7.53	0.014	.908	0.001	0.041	.840	0.001	
SEBT.PM	60.02 ± 11.59	60.90 ± 12.20	71.45 ± 14.79	71.45 ± 14.79	61.79 ± 11.08	62.10 ± 12.03	76.47 ± 16.64	76.47 ± 16.64	0.324	.571	0.005	0.347	.558	0.005	
SEBT.PL	58.71 ± 12.55	60.79 ± 11.70	59.32 ± 12.29	59.32 ± 12.29	59.89 ± 12.57	61.50 ± 12.40	64.59 ± 11.38	64.59 ± 11.38	0.118	.732	0.002	2.980	.089	0.042	
8 Weeks															
	4 Weeks		8 Weeks		4 Weeks		8 Weeks		Time		Time		Time		
	Group by Time	F(1,68)	p value	η^2	Group by Time	F(1,68)	p value	η^2	Group by Time	F(1,68)	p value	η^2	Group by Time	F(1,68)	p value
XEO	3.027	0.086	0.043	0.043	0.042	0.042	0.001	0.001	4.579	.036	0.063	4.755	.033	0.063	
XEC	1.743	.191	0.025	0.025	1.746	1.746	.191	0.025	1.599	.210	0.023	4.653	.035	0.064	
YEO	0.745	.391	0.011	0.011	0.269	0.269	.606	0.004	4.829	.031	0.066	0.119	.731	0.002	
YEC	0.360	.550	0.005	0.005	1.441	1.441	.234	0.021	0.115	.735	0.002	0.724	.398	0.011	
VEO	0.739	.393	0.011	0.011	1.565	1.565	.215	0.022	0.214	.645	0.003	5.530	.022	0.075	
VEC	3.882	.053	0.054	0.054	7.849	7.849	.007	0.103	0.010	.922	0.001	0.015	.903	0.001	
WBLT	0.002	.969	0.001	0.001	0.042	0.042	.838	0.001	4.043	.048	0.056	4.569	.036	0.063	
SEBT.ANT	1.106	.297	0.016	0.016	0.535	0.535	.220	0.022	0.738	.393	0.011	4.112	.047	0.057	
SEBT.PM	0.079	.779	0.001	0.001	1.132	1.132	.291	0.016	279.314	<.001	0.804	4.323	.041	0.060	
SEBT.PL	0.049	.825	0.001	0.001	1.381	1.381	.244	0.020	7.237	.009	0.096	4.292	.042	0.059	

Note: Quantitative variables are presented as the mean ± SD. XEO: mediolateral oscillations of the CoP in EO condition; XEC: mediolateral oscillations of the CoP in EC condition; YEO: anteroposterior oscillations of the CoP in EO condition; YEC: anteroposterior oscillations of the CoP in EC condition; VEO: displacement velocity of the CoP in EO condition; VEC: displacement velocity of the CoP in EC condition; WBLT: weight-bearing lunge test; SEBT.ANT: star excursion balance test anterior direction; SEBT.PM: star excursion balance test posteromedial direction; SEBT.PL: star excursion balance test posterolateral direction.

neurophysiological mechanisms underlying the stimulation of plantar cutaneous receptors.^{10,36} These findings agree with the results obtained in our study where GPR intervention combines plantar and joint receptor stimulation resulting in superior results due to this combination.^{10,36}

Concerning muscle activation role in postural control, Lynn et al.,³⁸ did not find differences between mediolateral oscillations in healthy individuals when performing training of intrinsic musculature of the foot. This is in contrast to the obtained results after GPR intervention and could be explained because during our intervention patients activate intrinsic and extrinsic muscles of the foot which has been deemed to play an important role in postural control.¹¹

4.2 | Manual therapy in HAV and dynamic balance

In presence of HAV, there are strength deficits that are related to balance impairments.^{4,11} The present study shows improvements in dynamic balance at the 3 directions of SEBT at 8 weeks. These positive results could be due to neurophysiological mechanisms underlying the manual stimulation of the plantar and joint receptors that were described before^{10,24,25,36} and the combination with muscle activation.^{37,38}

Literature reports that rigid tape improves dynamic balance in people with HAV deformity.^{20,39} There is also evidence that supports that plantar massage and joint mobilizations improve single limb dynamic balance in patients with CAI.^{22,31} Our findings in dynamic balance agree with the aforementioned results and it could be because both manual and taping interventions could enhance proprioceptive information of the cutaneous and joint receptors.^{10,20,31,39}

Previous investigators have also shown improvements in dynamic balance when training the intrinsic foot muscles in the healthy population,³⁸ individuals with excessively pronated feet³² and subjects with CAI,³⁷ which agree with the results of our study due to the isometric activations of the foot core.

4.3 | Manual therapy in HAV and ankle DFROM

Hurn et al.⁴ found that ankle DFROM was similar in people with and without HAV but they did not perform any intervention. However, when comparing their baseline data with ours, our participants show worse results in ankle DFROM. Our results show improvements in ankle DFROM with medium ES ($d=0.54$) after 8 weeks and agree with those reported by Abdalbari,¹⁴ who investigated the effect of manual therapy combined with active exercises and toe separator. Furthermore, it has been shown that the anterior reach of SEBT could be negatively influenced by a decreased ankle DFROM,²⁶ and our results show improvements in both the anterior reach of SEBT and ankle DFROM. Positive results in our study could be related to the proprioceptive information given by the joint mechanical receptors and the CNS responses when performing mobilizations combined with muscle activations.^{10,14,31}

Ankle passive joint mobilizations for decreased ankle DFROM has been widely explored in patients with CAI as well as Mobilizations With Movement with positive findings.^{22,31} These results agree with the obtained results after GPR intervention. The active component of GPR may play an important role in the integration of muscle activation and related subjective instability feeling due to ankle instability in patients with HAV.²²

5 | CONCLUSION

The obtained results suggest that GPR method is effective for improving mild to moderate HAV results in postural control parameters as mediolateral displacements and velocity of CoP displacement. It also improves dynamic balance in all three directions and ankle DFROM.

5.1 | Limitations and further investigation

The principal limitation of this study is the short and midterm evaluation. Future studies should examine the long-term results of the GPR treatment to determine the maintenance of the improvement over time. However, future studies should evaluate psychological, pain and quality of life. This pathology could affect patients self-concept and quality of life and should be addressed in a biopsicosocial model.⁴⁰

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