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The effect of two retraining programs, barefoot running vs increasing cadence, on kinematic parameters: A randomized controlled trial

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The aim of this study was to compare the effects of two 10-week non-laboratory-based running retraining programs on foot kinematics and spatiotemporal parameters in recreational runners. One hundred and three recreational runners (30 ± 7.2 years old, 39% females) were randomly assigned to either: a barefoot retraining group (BAR) with 3 sessions/week over 10 weeks, a cadence retraining group (CAD) who increased cadence by 10% again with 3 sessions/week over 10 weeks and a control group (CON) who did not perform any retraining. The footstrike pattern, footstrike angle (FSA), and spatial-temporal variables at comfortable and high speeds were measured using 2D/3D photogrammetry and a floor-based photocell system. A 3×2 ANOVA was used to compare between the groups and 2 time points. The FSA significantly reduced at the comfortable speed by 5.81° for BAR ($p < 0.001$; Cohen's $d = 0.749$) and 4.81° for CAD ($p = 0.002$; Cohen's $d = 0.638$), and at high speed by 6.54° for BAR ($p < 0.001$; Cohen's $d = 0.753$) and by 4.71° for CAD ($p = 0.001$; Cohen's $d = 0.623$). The cadence significantly increased by 2% in the CAD group ($p = 0.015$; Cohen's $d = 0.344$) at comfortable speed and the BAR group showed a 1.7% increase at high speed. BAR and CAD retraining programs showed a moderate effect for reducing FSA and rearfoot prevalence, and a small effect for increasing cadence. Both offer low-cost and feasible tools for gait modification within recreational runners in clinical scenarios.

KEYWORDS
gait retraining, metronome, running form, step rate, unshod

1 | INTRODUCTION

Running as a recreational activity has been reported to improve health and personal performance. However, between 26% to 74% of recreational runners have been reported to suffer running related injuries each year,[1-3] with an incidence of 30.1 injuries every 1000 h of running exposure.[4] Despite scientific and technological advances in footwear, training load control and running technique, the incidence of running related injuries has not changed significantly over the last 20 years. Contrary to an evolutionary perspective where running with forefoot strike (FFS) seems to be a common feature,[5] more than 90% of recreational runners present a rearfoot strike (RFS).[6,7] The prevalence of RFS has been associated with a rapid and high-impact peak in the ground reaction force, greater peak tibial acceleration and greater ankle stiffness,[5,8-13] and have been associated with a greater injury risk.[2,5] Therefore, alternatives to RFS should be explored, such as retraining programs with progressive transitions to FFS.

The effectiveness of acute changes in running retraining programs based on transitions to FFS has previously been examined in laboratory protocols.[10,11,13-17] Huang et al.[13] reported a reduction in impact loading by combining FFS and increase cadence. Moreover, Baggaley et al.[10] compared three components of real-time visual feedback during a single session which included: targeting a FFS using the footstrike angle (FSA), decreasing step length by 7.5% and decreasing vertical loading rate by 15%. They found the FFS component had the greatest impact on attenuation strategy compared to the other visual feedback components. This is further supported by Napier et al.,[14] who showed a decrease of step length and increase of cadence were associated with a reduction of vertical loading rates and breaking forces after an 8 session laboratory-based visual biofeedback training program. In addition, several acute programs have determined that an increase of cadence between 10%–15% is associated with a decrease of impact forces, in combination with a transition to FFS, and a decrease in the step length and duration.[15-17] Therefore, changes in running patterns associated with FFS and increase of cadence, have both been shown to reduce impact attenuation after running retraining programs, which may reduce the risk of injury.[2,5,18]

Despite the promising effects of acute laboratory-based running retraining programs, the use of sophisticated instruments, for example, force plates to provide real-time biofeedback, do not have good clinical utility due to availability and cost. Less sophisticated approaches which consider clinically applicable retraining programs, such as increasing the natural cadence using a metronome and transition to FFS, have been shown to be effective in terms of reducing impact forces.[12] Another non-laboratory and ecological alternative which encourages an FFS pattern is the transition to barefoot running.[19,20] In addition, barefoot running reduces ground-reaction force and loading rates and has been hypothesized to reduce the risk of injury.[20-22] Tam et al.,[23] explored an 8 week barefoot running program, and found a subgroup of responders with a similar pattern. These responders reduced the initial loading rate which could be explained by changes in the FSA and a reduction in the RFS prevalence. In contrast, a similar study showed no significant change in ankle angle, cadence, or stride length.[24] Therefore, there is still contradictory evidence on how barefoot running programs affect biomechanical outcomes, and little is known about increasing cadence in non-laboratory conditions and progressively over a long period of time.

Despite the number of studies that have considered running retraining programs, few have observed the effect on foot kinematics and spatiotemporal parameters within more ecologically valid, non-laboratory-based environments using non-sophisticated clinically feasible programs. Since the RFS prevalence reduction and the cadence increase have been associated with a reduction in the risk of injury,[2,5,18] the purpose of this study was to compare the effects of two non-laboratory-based 10-week running retraining programs on foot kinematics and spatiotemporal parameters in habitually shod recreational runners. The two retraining programs were: a 10-week barefoot running program, and a 10-week increased cadence running program. Both training scenarios were performed at comfortable speeds. The hypothesis was that both strategies of running retraining would reduce the RFS prevalence and FSA, and increase the cadence when compared to a control group.

2 | METHODS AND MATERIALS

2.1 | Participants

The subjects came from three different recreational running clubs in Andalusia (Spain), and the assessment protocol was performed in season. Inclusion criteria were as follows: all the subjects were healthy, had participated regularly in aerobic training at least three times per week during the last 2 years, had no history of injury in the previous 6 months that would limit training. As regards the exclusion criteria, subjects with cardiorespiratory pathologies that affect cardiovascular performance, such as asthma, allergies, diabetes, or other cardiac pathologies, were not included. This study conformed to the Declaration of Helsinki (2013) and

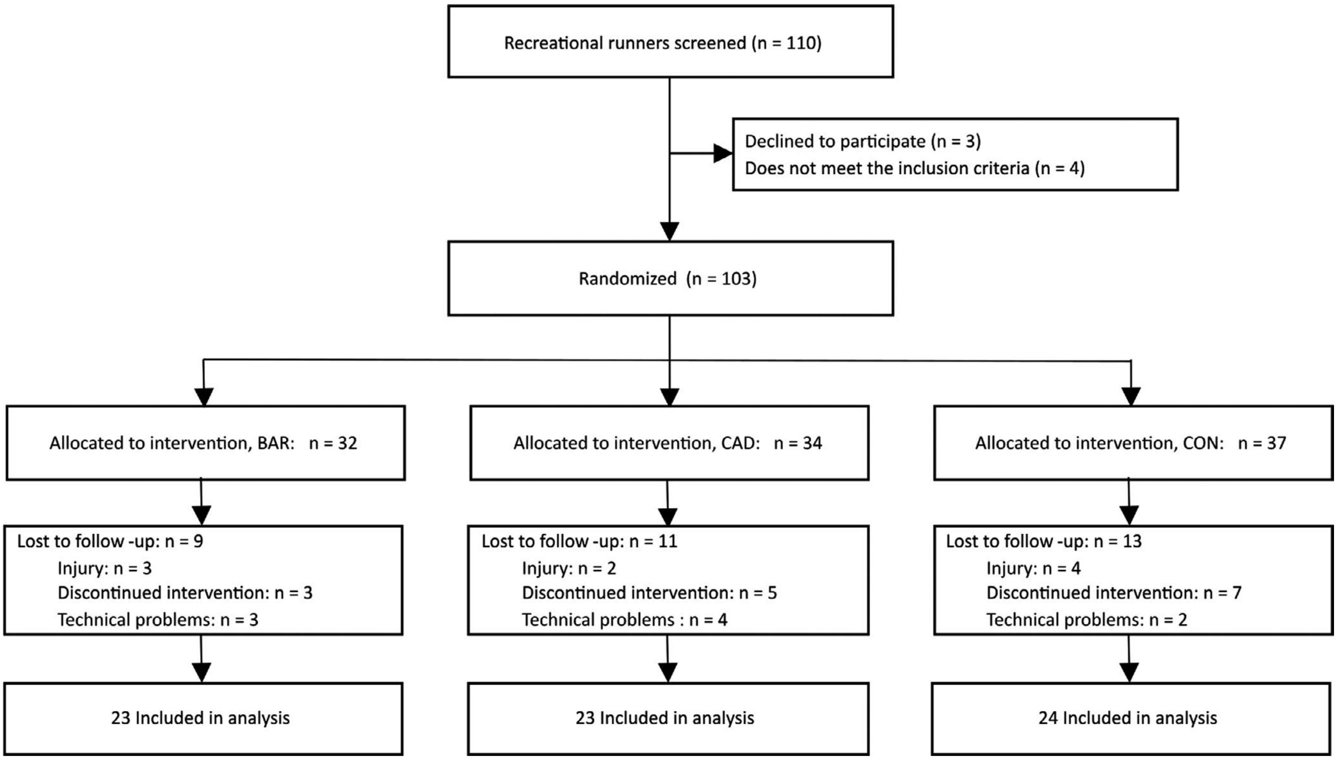

FIGURE 1 Flowchart of participant recruitment. BAR, Barefoot group; CAD, Cadence group; CON, Control group

was approved by the Ethics Committee at the University of Granada (No. 788/CEIH/2019). Each participant was informed about the study and signed an informed consent. They were then randomly assigned to one of three groups; a barefoot retraining group (BAR), a cadence retraining group (CAD) and a control group (CON). A recruitment flowchart of the participants is shown in Figure 1. Those participants who discontinued the intervention were due to injuries unrelated to the intervention or personal reasons.

An a priori sample size calculation was performed using the G*Power software for ANOVA: repeated measures, with a between groups analysis. The following parameters were selected: moderate effect size $f = 0.252$, α level of 0.05, a power level of 0.95, Noncentrality parameter $\lambda = 16.500$, critical $F = 3.142$. The sample size required was determined to be at least 66 participants to assess the three groups at two assessment time points.

2.2 | Retraining program

The BAR and CAD groups performed three retraining sessions per week, the first 4 weeks during the warm-up and the last 6 weeks were individual retraining sessions (Table 1). In addition, they received a weekly training diary, to check that there was at least an 85% adherence and daily retraining intensity using a 0–10 Borg scale score.[25] The BAR group performed periods of barefoot retraining following a previously published methodology.[26] This consisted of the progressive inclusion of barefoot

TABLE 1 Weekly retraining of the experimental groups (repeated 3 times a week)

Weeks	Barefoot retraining group	Cadence retraining group	Total weekly time (min)
1	15′ CS	15′ CS	45
2	15′ CS	15′ CS	45
3	20′ CS	20′ CS	60
4	20′ CS + 5 × 80 m PR-HS	20′ CS	60
5	25′ CS	25′ CS	75
6	25′ CS + 5 × 80 m PR-HS	25′ CS	75
7	30′ CS	30′ CS	90
8	10′ CS + 10′ MS + 10′ CS	30′ CS	90
9	35′ CS + 5 × 80 m PR-HS	35′ CS	105
10	10′ CS + 10′ MS + 10′ CS + 5′ MS + 5′ CS	40′ CS	120

Abbreviations: CS, Comfortable speed; MS, Medium speed; PR-HS, Progressive runs building to high speed.

running on a soft, flat, grass, or non-slip surface (ie, a football pitch), at comfortable speed, medium speed and with progressive runs building to high speed (Table 1). Increases in running speed have been shown to be effective in reducing the prevalence of RFS.[7,26] The CAD group performed a retraining program based on an increase of 10% of their natural cadence at comfortable speed determined at baseline following the protocol suggested by previous studies,[15-17] and a digital metronome was used to provide auditory feedback.[12] The CAD group was asked to strike their feet to the beat of the metronome and, to control the comfortable speed, the retraining sessions were performed either on a treadmill or on a 400-meter running track (controlling the pace by GPS or lap time) both within the same sporting facilities. The choice depended on the runners' abilities, those who had problems following the comfortable speed and the increase in cadence using the metronome carried out the intervention on the treadmill. The runners' coaches and the principal researcher conducted the retraining programs in person, to ensure runners did not experiment with other methods. The principal researcher provided the coaches and runners with the week's retraining task both in writing and verbally on the first training day of the week. Both retraining groups performed progressive, and similar volume and intensity programs. Finally, the CON group did not perform any retraining, and the runners continued with their usual training load. All groups continued with their training loads and habits outside of the retraining sessions, the BAR group wore their running shoes, and the CAD group did not use a metronome, during competitions, high intensity runs on the track or long distance runs in the outdoors. Apart from the instructions described above, none of the retraining groups received any other technical instruction and participants were advised to decrease the intensity of training or even abandon it when pain or injury occurred.

2.3 | Materials and testing

Body height and weight were measured to the nearest 0.1 kg and 0.1 cm, respectively, (SECA Instruments), and body mass index (kg/m^2) was calculated. Additionally, body composition was measured using bioimpedance testing (Inbody 230; Inbody). Two methods were used to record foot kinematics. Firstly, three-dimensional FSA was evaluated using a Simi Motion Capture System composed of eight high-resolution cameras operating at 100 Hz and the Simi Motion software v.9.2.2. (Simi Reality Motion Systems GmbH). The FSA was examined over a 15 s period (with more than 40 steps), using reflective markers on the running shoes, and computed as the sagittal plane angle of the foot segment, with reference to the lab co-ordinate system at initial contact[27] using Visual3D (C-Motion). The marker data were filtered with a cut-off frequency of 8 Hz via a fourth-order Butterworth low-pass filter.[11] Initial contact was defined using the technique described by Handsaker et al.,[28] which was cross checked against the video recordings. Angles greater than 8.0° were represented as RFS, angles from 8.0° to −1.6° were midfoot strikes and angles less than −1.6° as FFS.[27] Secondly, the foot strike pattern was determined using two cameras within the Simi Motion Capture System, which were placed 4 meters perpendicular to the center of the treadmill using the methods described by Latorre-Román et al.[29] The classification of RFS or non-RFS using these techniques has been shown to have a greater accuracy in determining a RFS (interrater accordance: 0.981), than in deciding between RFS, midfoot strike, and FFS (0.893).[30]

Spatiotemporal parameters were recorded using a floor-based photocell system (Optogait; Microgate), mounted on a professional treadmill (Woodway Pro XL) at a sampling frequency of 1000 Hz, over a 120 s period (with more than 330 steps). Optogait has been previously validated for the assessment of spatiotemporal parameters during running, reporting small systematic biases and random errors and very high ICCs and Pearson coefficients (>0.9).[31] The parameters obtained were; contact time (CT), and its three subparts, landing time (from the footstrike until the whole foot is in contact with the ground), midstance time (from when the whole foot is in contact until the heel is off the ground), propulsive time (from the moment the heel is off the ground until the foot is completely off the ground). In addition, flight time (FT), step length (SL), and cadence were recorded, which were previously defined by García-Pinillos et al.[32]

2.4 | Test protocol

Participants did not perform any heavy physical exertion for 72 h prior to data collection. They were asked to run consistently on a professional treadmill at their self-selected comfortable training speed and self-selected high speed, defined by a self-declared recent best 5 km pace in the current season. As the purpose was to evaluate the effect of progressive periods of running retraining (eg, barefoot running) on habitually shod runners, all participants performed the running protocol by wearing their own running shoes in the pre- and post-test.[33] Before the running test, they performed an 8 min warm-up on the treadmill at their self-selected comfortable training speed.[10,32] Once the comfortable speed was selected and the warm-up completed, the data collection was carried out with a total period of 120 s. The indications for a comfortable speed were: "Run comfortably at a speed that allows you to speak and breathe easily". Participants' test speeds were recorded, and the same protocol was repeated at the same speeds after the 10-week running retraining programs. In order to control the potential effect of fatigue during the running test, the intensity was measured using the 0–10 Borg scale.[25]

2.5 | Statistical analysis

Data were analyzed using SPSS, v.25.0 for Windows (SPSS Inc.) and the significance level was set at $p < 0.05$. Tests of normal distribution and homogeneity were conducted on all data before analysis using the Kolmogorov-Smirnov and Levene's tests, respectively, and all data were found to be suitable for parametric testing. Descriptive data were reported in terms of means and standard deviations (SD). A 3 × 2 analysis of variance (ANOVA) with repeated measures was conducted to examine the effects of time (pre-test and post-test) and groups (BAR, CAD, and CON) on each variable. Paired *t*-tests were used as post-hoc tests when a significant interaction between groups and time was detected. Additionally, effect sizes for group differences were expressed as Cohen's d [34]; effect sizes are reported as: trivial (<0.2), small (0.2–0.49), medium (0.5–0.79), and large (≥0.8).[34] Regarding the RFS prevalence, a chi-squared (χ^2) test was used to compare the differences between groups, in addition, McNemar's tests were used to analyze the within-group differences.

3 | RESULTS

Regarding the retraining sessions, the average attendance for the BAR program was 85% with an average score of 3.5 out of 10 on the Borg scale, with the CAD having an average attendance of 86% with an average score of 3.6 out of 10 on the Borg scale. In each acquisition period, no participants indicated a score >6 out of 10 in the Borg scale during the running protocol. At baseline, no significant differences were observed for any of the demographic and training characteristics between the three groups (Table 2).

3.1 | Foot kinematics

A significant Time × Group interaction effect was seen for the foot kinematics, Figure 2. Further post hoc paired *t*-tests showed a decrease in FSA after retraining in the BAR group by 5.81° ($p < 0.001$; Cohen's $d = 0.749$) and 6.54° ($p < 0.001$; Cohen's $d = 0.753$) at comfortable and high speed, respectively. Similarly, the FSA decreased in the CAD group by 4.84° ($p = 0.002$; Cohen's $d = 0.638$) and 4.71° ($p = 0.001$; Cohen's $d = 0.623$) at comfortable and high speeds, respectively. In contrast, the FSA increased in the CON group by 2.70° ($p = 0.047$; Cohen's $d = 0.340$) at high speed, and no significant changes were found at comfortable speed, after retraining. A significant reduction in RFS prevalence was also seen in the BAR group, for both the left and right feet ($p = 0.006$ and $p = 0.011$), after retraining at comfortable speed only. No significant differences were found for RFS in the CAD and CON group at both speeds after retraining.

3.2 | Spatiotemporal parameters

A significant Time × Group interaction effect was seen for spatiotemporal parameters, Figure 3. Further post hoc paired *t*-tests showed that at the comfortable speed; cadence

TABLE 2 Demographic and training characteristics, mean (SD)

	BAR (***n*** **= 23, 39.1% females)**	**CAD** (***n*** **= 23, 47.8% females)**	**CON** (***n*** **= 24, 29.1% females)**	***p*-Value**
Age (year old)	31.4 (7.37)	29.39 (7.41)	29.21 (7.07)	0.543
Height (cm)	175.3 (10.39)	173.13 (7.23)	173.08 (6.72)	0.593
Body mass (kg)	73.0 (12.21)	69.77 (11.27)	70.22 (11.47)	0.598
Body mass index (kg/m^2)	23.7 (2.95)	23.16 (2.53)	23.34 (2.84)	0.795
Fat mass (%)	21.77 (9.44)	20.09 (6.41)	17.36 (5.07)	0.111
Muscle mass (%)	44.96 (4.63)	44.78 (4.14)	46.75 (3.39)	0.192
Comfortable speed (km/h)	9.87 (1.11)	10.15 (1.04)	10.45 (0.86)	0.150
High speed (km/h)	14.03 (2.02)	14.24 (1.93)	15.13 (1.35)	0.095
Training experience (years)	3.43 (1.33)	3.43 (1.65)	3.00 (1.20)	0.457
Running sessions per week	3.76 (1.00)	3.91 (1.12)	3.50 (0.98)	0.625
Training volume per week (km)	26.95 (14.20)	21.87 (11.67)	26.42 (9.34)	0.287
Competitions per year	10.57 (7.87)	8.04 (6.59)	7.25 (4.32)	0.202

Abbreviations: BAR, Barefoot group; CAD, Cadence group; CON, Control group; SD, Standard deviation.

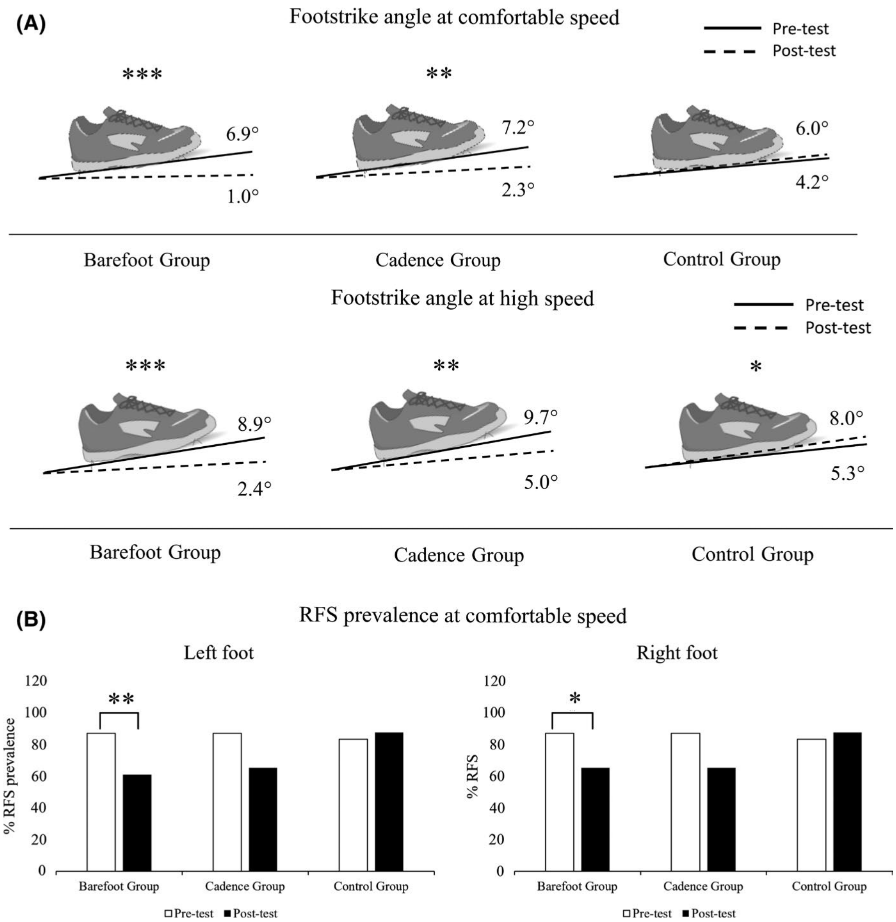

FIGURE 2 (A) The footstrike angle (FSA) at comfortable and high speed for pre-test (solid lines) and post-test (dashed line) for each group. (B) rearfoot strike (RFS) prevalence in percentage of runners using a RFS at comfortable speed, by the foot strike pattern (left and right foot) for pre-test and post-test for each group. *denotes $p < 0.05$; **denotes $p < 0.01$; ***denotes $p < 0.001$

increased for the CAD group ($p = 0.015$; Cohen's $d = 0.344$) and decreased for the CON group ($p = 0.031$; Cohen's $d = 0.326$); and landing time decreased for the BAR and CAD groups ($p = 0.001$; Cohen's $d = 0.591$ and $p = 0.008$; Cohen's $d = 0.472$), respectively after retraining. At high speed, further post hoc paired t-tests showed that; SL decreased for the BAR group ($p = 0.030$; Cohen's $d = 0.105$) and increased for the CON group ($p = 0.001$; Cohen's $d = 0.251$); and cadence increased for the BAR group ($p = 0.031$; Cohen's $d = 0.412$) and decreased for the CON group ($p = 0.001$; Cohen's $d = 0.534$); and landing time decreased for the BAR group ($p = 0.004$; Cohen's $d = 0.304$) after retraining. No significant differences were found for any other spatiotemporal parameters at both speeds after retraining.

4 | DISCUSSION

The purpose of this study was to compare the biomechanical effects of two different 10-week non-laboratory-based running retraining programs on foot kinematics and spatiotemporal parameters at comfortable and high speeds in recreational runners. To our knowledge, this is the first study to explore the effect of these retraining protocols on foot kinematics and spatiotemporal parameters in recreational endurance runners. The main findings of this study were: (1) FSA was significantly reduced for both the BAR and CAD groups with a moderate effect size, (2) the BAR group decreased RFS prevalence at comfortable speed with a moderate effect size, (3) the cadence was significantly increased for the CAD group at comfortable speed and for BAR at high speed after retraining with small effect sizes, and (4) the CON group decreased cadence at both speeds and increased SL at comfortable speed after the two time points with small effect sizes. Both retraining programs, short-periods of barefoot running and increasing the cadence by 10%, produced significant kinematic changes in FSA, RFS prevalence, and spatiotemporal parameters with small to moderate effect sizes. Moreover, no adverse events relating to the exercise program were reported.

4.1 | Foot kinematics

Compared to the pre-test, the FSA was reduced significantly after BAR and CAD programs at comfortable and high speeds. The whole BAR retraining group reduced the FSA, showing a group mean of 1.0° and 2.4° at comfortable and high speeds after retraining, respectively. Altman et al.,[27]

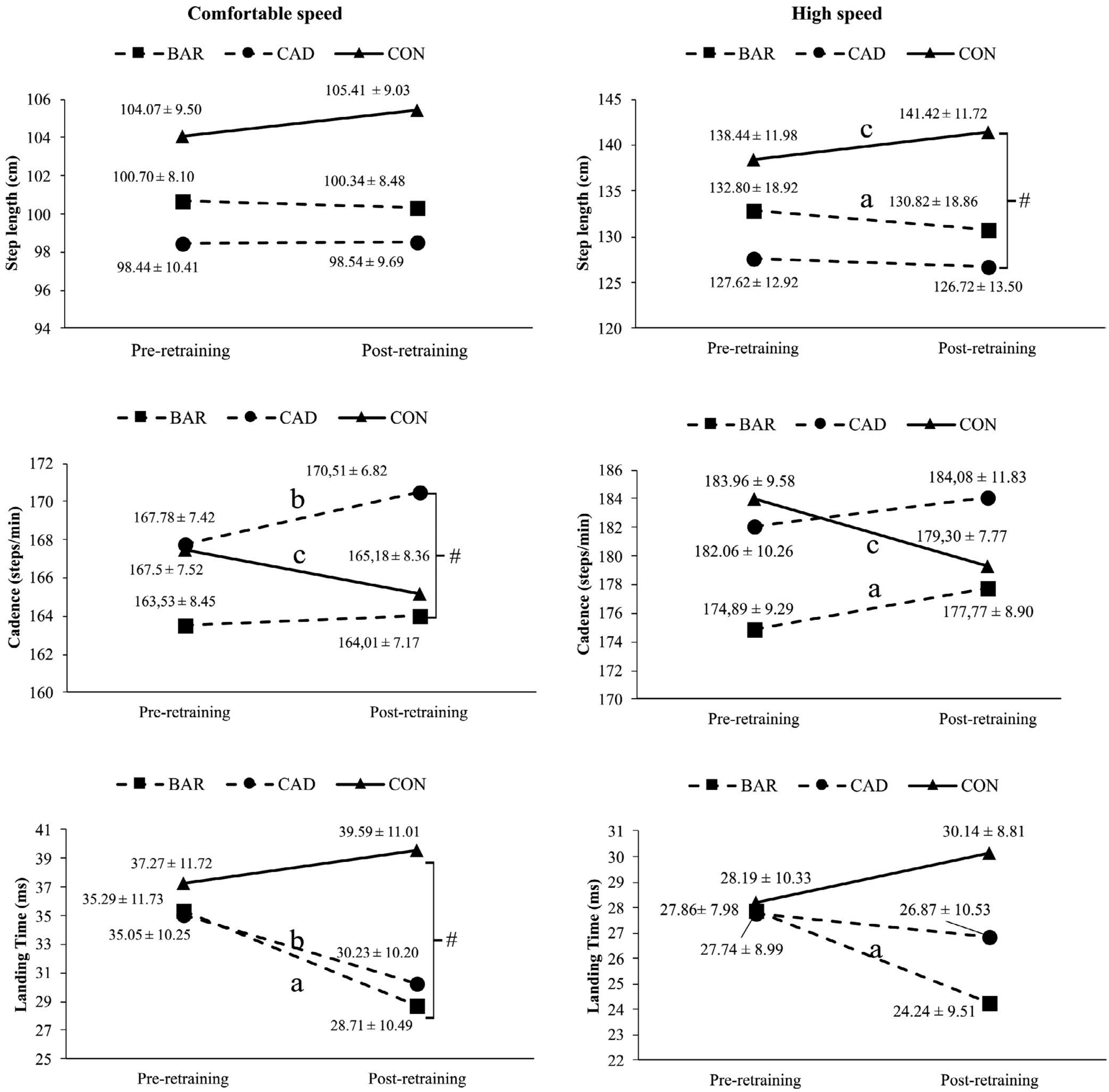

FIGURE 3 Effect of 10-week retraining programs on step length, cadence, and landing time at comfortable speed (left column) and high speed (right column). Barefoot group (BAR); Cadence group (CAD); Control group (CON); [a]for BAR, [b]for CAD, and [c]for CON indicate significant difference between pre-retraining and post-retraining ($p < 0.05$); [#]indicates an interaction effect between groups ($p < 0.05$)

defined a midfoot strike with a FSA between 8° and −1.6° based on the strike index using plantar pressure regions. Thus, the BAR group would be considered a midfoot strike after 10 weeks of barefoot retraining. Conversely, an 8 week retraining study based on the combination of barefoot walking and running did not change overall group kinematics.[23] Unlike this study, which carried out only 6 out of 24 continuous barefoot running sessions, we planned all sessions with continuous barefoot running at a comfortable speed, with the addition of progressive runs building to high speed and medium speed barefoot running in some retraining sessions. This suggests that the load and intensity of these programs is a determining factor for producing the switch from RFS to midfoot strike or even to FFS. Similarly, the CAD group reduced the FSA, showing a group mean of 2.3° and 5.0° after the retraining program at comfortable and high speeds. The transitions from RFS to non-RFS during laboratory retraining programs have previously demonstrated a reduction of the ankle joint stiffness, impact forces and lower limb load,[10-13] associated with a lower injury risk.[2,5]

Using a visual 2D video-based determination of RFS (heel strike) and non-RFS (non-heel strike), only the BAR group reduced the RFS prevalence at a comfortable speed after the retraining program. However, a similar study which explored barefoot and cadence retraining programs in adolescents did not find any significant changes.[35] They suggested that the rapid growth (ie, body height and weight) and the deterioration of biomechanics and coordination in adolescents as potential influential factors. Nevertheless, this is supported by other barefoot retraining programs which have been reported to result in effectively reducing RFS prevalence in runners measured by visual 2D video-based analysis in long-distance regional or national athletics championship runners.[19] They found a decrease from a RFS prevalence of 80% at baseline to 43% after a 10-week barefoot retraining program. Similarly, we found a decrease for the BAR group from a RFS prevalence of 87% at baseline to 63% at post-test within recreational runners. This highlighting the importance of sample characteristics on outcome variation in similar barefoot retraining programs, and the importance of intrinsic and extrinsic factors within and between individuals. Since using 2D video-based visual determination can only discriminate between RFS and non-RFS, only large changes can be determined using this method. Therefore, only significant changes were found for BAR by 2D visual determination, whereas using a 3D method, a significant reduction in the FSA was detected for both groups.

The RFS prevalence in road races with recreational runners has been widely studied,[6,7,36] however, few studies have tested the effects of retraining programs at high speeds[19] Our results demonstrated a reduction in FSA and RFS prevalence following BAR and CAD retraining programs at high-speed. Which may be related to less contact time and greater flight time,[7] proposed as one of the models associated with elastic energy and stiffness of the leg muscles to increase running economy.[37,38]

4.2 | Spatiotemporal parameters

The running retraining programs also induced changes in the SL, the cadence and the landing time. A recent comparison of retraining based on increasing cadence vs. a transition to FFS by Futrell et al.[12] showed that cadence retraining increased the cadence by 7.2%, decreasing the vertical average load rate by 16% after retraining, however, the transition to FFS retraining increased the cadence by 6.1% after retraining, with a greater reduction of impact load (vertical average load rate) which decreased by 49.7% and vertical instantaneous load rate which decreased by 41.7%. Thus, Futrell et al. suggested that a non-RFS is a more crucial key factor for impact load reduction than cadence. In our current study, the CAD group increased cadence by 2% at comfortable speed, from 167 steps/min to 171 steps/min, after the retraining and the BAR group by 1.7%, from 175 steps/min to 178 steps/min after the retraining at high speed after the retraining program. These findings are not considered as meaningful changes by the authors for cadence, as the target was a 10% increase in cadence for the CAD group, and at least a 6%–7% increase has been shown to produce a significant reduction in impact loads.[12] However, we suggest that a combination of reduction of FSA and decreasing of RFS prevalence could lead to a reduction of impact loads,[12] although, these results need to be evaluated and discussed in real-world applications. The BAR group showed significant changes decreasing landing time after the 10 weeks at both speeds. This change could be related to the transition from RFS to non-RFS where the time and angle range of movement from footstrike to flat foot on the ground is reduced due to an angle at footstrike being close to 0°.[19] In contrast to the BAR and CAD groups, the CON group showed minor changes with a 2% decrease in cadence at both speeds, and an increase in SL at high speed, after the two time points. The use of traditional running footwear has been associated with a high RFS prevalence and SL, and a low cadence.[2,5-7] As for the CON group, this could be due to a natural tendency of endurance runners, who habitually wear shoes, which could lead to an increase in FSA, and may be related to a high RFS prevalence, decreased cadence and increased SL.

4.3 | Limitations

Several limitations need to be acknowledged in the current study. Although this study considers the effect of two 10-week running retraining programs in healthy recreational runners, the extrapolation of these results to injured, elite, juvenile, or long-distance competitive runners should be done with caution. Due to the small sample size of the current study, it was not possible to analyze effects by gender. The 10-week effects of the retraining programs were tested, so the longer-term effects of these programs are unknown. In addition, the runners presented relatively high cadences at baseline (166 steps/min and 180 steps/min at each speed), making the 10% increase set by the study difficult to achieve (183 steps/min and 198 steps/min).

5 | PERSPECTIVES

Despite the promising effects of acute laboratory-based running retraining programs used to try to reduce the incidence of injury,[10,11,13-16,39] to our knowledge, little is known about the effect of ecologically valid, non-laboratory-based environments using non-sophisticated clinically feasible programs on foot kinematics and spatiotemporal parameters in recreational runners.

Changes in running patterns associated with FFS and increases to the cadence, have both been shown to reduce impact attenuation after running retraining programs.[10-13,15-17] Running barefoot encourages a midfoot strike pattern and could reduce ground-reaction force and loading rates in recreational runners[19,20]; thus, it has been hypothesized to be a valid non-laboratory and ecological alternative to reduce the risk of injury.[20-22] Therefore, our findings represent a contribution to our understanding to the knowledge on running retraining effects in foot kinematics and spatiotemporal parameters by assessing these two feasible tools. Both methods are useful for clinical applications for trainers, physiotherapists, or other clinicians working with recreational runners who want to reduce footstrike angle and rearfoot strike prevalence for practical purposes.

6 | CONCLUSIONS

The BAR and CAD retraining programs showed moderate reductions in foot strike angle and prevalence of rearfoot strike. Cadence did not effectively increase for the BAR and CAD groups, showing minor changes together with a reduction in step length after the two retraining programs. The two proposed running retraining programs appear to reduce footstrike angle and rearfoot strike prevalence, however, they were not as effective in increasing cadence after 10 weeks of progressive retraining sessions.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

AM-M, PAL-R, and VMS-H defined the experimental design and conceptualized the approach. AM-M, EM-P, and GD-G collected the data. PAL-R and JR carried out the statistical analysis. AM-M wrote the paper. All authors reviewed the manuscript for scientific content. All authors have read and agreed to the published version of the manuscript.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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