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Does lateral ankle sprains history influence running biomechanics: a cross-sectional investigation

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ABSTRACT

Objective: To report locomotor analysis, i.e., walking and running, between runners with different clinical history of ankle sprain, i.e., healthy (HEA), copers, chronic ankle instability (CAI) and recent ankle sprain (LAS).

Design: Cross-sectional cohort study.

Setting: laboratory setting.

Participants: 74 participants (Healthy: n = 24, Copers: n = 15, CAI: n = 18, LAS: n = 17), including 49 men and 25 women (age: 25.3 years; height: 178 cm; weight: 73.3 kg)

Methods: Eligible participants were enrolled and assigned to their corresponding category, based on these eligibility criteria i.e., HEA, COPERS, LAS or CAI. To be included, all participants had to be active runners. Each runner underwent a complete clinical examination (i.e., ROAST) of the ankles as well as an analysis of the locomotor biomechanics on the treadmill. Participant first warmed-up during 3 minutes at a comfortable walking speed that represented their day-to-day walking speed. Then, they ran during 5 minutes at a speed that would allow them to run for one hour while still being able to converse. The analysis was carried out for 20 seconds, at the end of both sets, at a frequency of 1000 Hz.

Main Outcome Measures: Pain, swelling, dorsiflexion range of motion, arthrokinematics, static and dynamic postural balances and physical activity level were collected during the clinical assessment. Gait parameters (kinetic parameters and spatiotemporal parameters) were analyzed on an instrumented treadmill.

Results: Significantly reduced recovery, an index measuring the efficiency of locomotor mechanism, and reduced step duration were reported for the participant with recent history of ankle sprain during walking. There were no significant differences of running biomechanics between groups.

Conclusion: Ankle sprain could alter walking gait compared to healthy individual without affecting running.

1. INTRODUCTION

Although running is one of the most popular sports in the world, with several advantages, it also presents a high risk of injuries, especially in the lower extremities. The incidence rates of injuries are rated from 7,7 to 17,8 per 1000h of running (Van Poppel, 2021). The ankle sprains incidences vary according to profiles, with 21% among elite runners and 10% among recreational runners (Freteur, 2021). Also note that female and lower age groups are at higher risks of presenting an ankle sprain (Doherty, 2013). Ankle sprains are one of the most prevalent lower limbs injures. One out of every three women and one out of every four men have experienced a sprained ankle at some point in their lives (Delahunt, 2018). Ankle sprains are the seventh most common disorder in runners and the first traumatic running injuries (Kakouris, 2021).

Most individuals who sprain their ankle will recover to pre-injury levels of physical function and are classified as copers, however, 40% will develop Chronic Ankle Instability (CAI) (Miklovic, 2018). CAI is a condition that refers to those who report suffering from an episode of ankle sprain with lasting symptoms. Sustained symptoms may include pain, oedema, a giving away sensation and general instability. (Delahunt, 2018 ; Miklovic, 2018). Copers is a status that refers to those who have suffered from a lateral ankle sprain at least 12 months ago and that required immobilization of the ankle or discharged of the injured limb for at least 3 days (Gribble, 2016) but returned to high level activities without recurrent injury or loss of function (Wikstrom, 2012).

Hertel et al. (2019) described in-depth the mechanisms of CAI (Figure 1). A sprained ankle with primary tissue damage will impact the injury's self-organization. We could find pathomechanical deficiencies (laxity, arthrokinematics restrictions, ...) that may be accompanied by sensory-perceptual impairments (diminished somatosensorial, pain, ...) and motor-behavioral impairments (altered reflexes, neuromuscular inhibition, ...). These three major deficiencies can themselves lead to CAI. The impact of ankle sprain and CAI on the sensorimotor system has been highlighted. Mechanical restriction of ankle dorsiflexion is known to impact lower limb kinematics (Lebleu, 2018). However, it is unclear how a lateral ankle sprain history could affect gait and more particularly running biomechanics.

Running rehabilitation is rendered inefficient due to a lack of understanding of the biomechanical effects of ankle sprain or CAI. Many investigations on biomechanics in runners with CAI and ankle sprain have already been conducted. However, most of these studies only compared two groups of people, and several of them did not specify whether the control group was made up of healthy runners or COPERS. Colapietro et al. (2020) used wearable sensors to examine biomechanical variables in runners with and without CAI. This evaluation was carried out during two 1600m outdoor track runs at a slow and fast pace. This experiment revealed significant biomechanical differences in ground contact duration and impact g on the slow run, as well as pronation excursion on the fast run. However, no selection criteria for each group were specified. As a result, we don't know what kind of athlete is in the control/healthy group and whether these athletes are COPERS or people who had never had an ankle sprain. In addition, Koldenhoven et al. (2022) matched ankle sprain copers to CAI patients to assess running gait kinematics, kinetics, and surface electromyography all at the same time. A difference in ankle inversion was found during certain phases of the running stride cycle. This study, however, solely compares copers and CAI participants. It allows us to make no comparisons to subjects who have never had an ankle sprain. Moreover, the lack of running rehabilitation efficiency is also due to conflicting results for running biomechanics in people with CAI compared to healthy subjects or copers.

Therefore, this study aimed to fill the gaps in the literature by comparing four specific groups, i.e., healthy subjects (HEA), subjects with ankle sprains (LAS), subjects with ankle sprains but who are recovered (COPERS) and subjects with chronic ankle instability (CAI). This would allow us to emphasize the biomechanical alterations existing in these participants, compare them, and then direct therapists towards an effective therapy, potentially lowering the likelihood of sprain recurrence in runners. Thus, we established hypothesis that stated that there were biomechanical differences between each category of runners.

2. METHODS

This cohort study followed the STROBE checklist recommendation. During the recruitment, all participants signed an informed consent form. The procedure for this study complies with the local ethical committee (CEHF: B403201523492).

2.1. PARTICIPANTS

During the recruitment phase, potential participants completed three questionnaires: the Foot and Ankle Ability Measure, ADL subscale and Sport subscale, and the Cumberland Ankle Instability Tool. (Gribble, 2016) Eligible participants were enrolled and assigned to their corresponding category, based on these eligibility criteria (TABLE 1), i.e., HEA, COPERS, LAS or CAI. To be included, all participants had to be active runners, which was defined as having at least 6 months of consistent running experience and being able to run for an hour without stopping. A history of surgery on the lower limb, including the lower back, with no therapy, cardiovascular illness, neurological disease, degenerative condition, current pregnancy, and being a minor were all exclusion criteria for the four groups.

TABLE 1. Eligibility criteria according to their corresponding category.

<i>Name</i>	<i>Eligibility criteria</i>
Healthy runners (HEA)	<ol style="list-style-type: none">1. Has never suffered from any ankle trauma, including a lateral ankle sprain.2. CAIT > 24, FAAM > 90% (appendix 1) for ADL subscale and >80% for sports subscale (Gribble, et al., 2013)
Copers runners (COPERS)	<ol style="list-style-type: none">1. Has suffered from a lateral ankle sprain that required immobilization of the ankle or discharge of the injured limb for at least 3 days.2. No signs of ankle instability or snatch for at least 12 months3. CAIT > 24, FAAM >90% for ADL subscale and >80% for sports subscale (Gribble, et al., 2013)
Chronic ankle instability (CAI)	<ol style="list-style-type: none">1. Report suffering from a substantial episode of lateral ankle sprain, subsequent recurring sprains, occurrences of the ankle giving way, or self-reported deficiencies in ankle function for more than a year after the initial sprain. (Miklovic et al., 2018)2. Hasn't had any episode of lateral ankle sprain in the last year.3. CAIT ≤ 24, FAAM < 90% for ADL subscale and < 80%for sports subscale
Runners presenting a lateral ankle sprain (LAS)	<ol style="list-style-type: none">1. Is currently suffering and recovering from an episode of lateral ankle sprain that causes pain, swelling or adaptation, or even interruption, of daily activities OR has had an episode of lateral ankle sprain in the last year.2. CAIT ≤ 24, FAAM < 90% for ADL subscale and < 80% for sports subscale

2.2. TESTING PROCEDURE

Following the completion of the questionnaires, participants had an individual appointment at the Neuromusculoskeletal laboratory, movement analysis laboratory in Brussels. Those data collections took place from July to September 2023. Each participant received a ROAST assessment as well as a running biomechanics assessment. An information and consent letter were signed by every participant prior to any assessment.

The ROAST clinical assessment (Delahunt, 2018) included:

1. **Ankle Pain: Numeric Rating Scale for pain (NRS).** Single 11- point numeric scale used to reflect the participant's pain intensity (0-11), with "0" meaning "no pain at all" and 10 meaning "the worst pain imaginable" (Gillian, 2011).
2. **Ankle Swelling (appendix 4): Figure of Eight.** Test performed with A one-quarter-inch wide and retractable measuring tape. The participant had to be seated comfortably in a long sitting position with half of the calves out of the table. The measured foot had to be placed in a neutral dorsiflexion position and both feet were measured. (Figure 5)
3. **Dorsiflexion ROM (appendix 5): Weight Bearing Lunge test.** The participants were required to place their foot perpendicular to the wall and lunge forward to touch a vertical line on the wall with their knee, while keeping their tested foot and heel in contact with the floor (Bennell K, 1998). Each foot was tested three times, the result was the mean of the three values, and the measurement consisted in the distance from the hallux to the wall. (Figure 5)
4. **Ankle Arthrokinematics (appendix 6): Posterior Talar Glide test.** This test was used to measure the posterior glide of the talus in the ankle mortise. The participant had to sit on the end of the table and relax, his ankle was then placed into a subtalar neutral position while we gently pushed posteriorly the talus and the ankle into dorsiflexion, until we felt a firm capsular end (Denegar, 2002). The measure was taken with an inclinometer app on a smartphone. The phone was in an armband which was attached to the tested leg and the inclinometer was recalibrated before doing the test (Figure 5).
5. **Static postural balance (appendix 7): Balance Error Scoring System (BESS):** The participant had to hold 3 positions during 20 seconds, once with

opened eyes, then with closed eyes while being on firm surface and then on foam surface. The 3 positions were: double leg stance, tandem stance, and single leg stance. Errors were counted in each position: moving the hands off the hips, opening the eyes, step, stumble or fall, abduction, or flexion of the hip more than 30°, lifting the forefoot or heel off the support surface, remaining out of the specified stance position for more than 5 seconds (Docherty, 2006). One error or several simultaneous errors counted as 1 point, and the maximum score for any single stance position was 10 (Figure 5).

6. **Dynamic postural balance: YBT (Sipe, 2019) - modified (appendix 8):** A "Y" was drawn on the ground using a tape, with an equivalent angle between each branch. A meter had been drawn on the longer branch of the "Y" to be able to measure the patient's result. The participant stood with the tested foot in the center of the "Y", the heel being on the "zero" drawn on the tape. He then had to face each branch while trying to reach the furthest on the longer branch with the other leg. There were three directions: anterior, posterior-medial, and posterior-lateral. Both legs were tested, each direction was tested three times, and the result was the mean of the three values. (Figure 5).
7. **Walking Gait: visual evaluation for antalgic gait.** Walking was visually analyzed.
8. **Physical activity level (appendix 9): Tegner activity level scale.** Score from 1 to 10 regrouping different physical activities at each step (Figure 5).
9. **Specific patient-reported outcome measure:** FAAM – Foot and Ankle Ability Measure (Figure 7) and CAIT (Figure 8).

We avoided potential bias by organizing a clear measurement procedure. One experimenter was exclusively in charge of the running assessment and the second of the clinical assessment. This permitted us to avoid inter-experimenter bias. Moreover, the analysis consisted of the clinical assessment, then the running assessment. This analysis order was respected for every participant.

Every participant was then assessed on an instrumented treadmill fitted with load force captors. Each runner received an 8-minute treadmill warm-up, since Souza, R. B. (2016) research has shown that this period is required to adapt the running stride on a treadmill. The participants were instructed to walk during the first 3

minutes and to choose a walking speed that matched their day-to-day walking speed. The biomechanical analysis was conducted during the last 20 seconds of the walking bit, at a recording frequency of 1000 Hz. Table 2 details the biomechanical variables of interest for walking. Then, the participant was instructed to run for 5 minutes and to choose a running speed that would allow them to run for one hour while still being able to converse, which corresponds to a 3 out of 10 on the modified Borg Rating of Perceive Exertion scale. The biomechanical variables were recorded at the 5th minute of running for 20 seconds at a recording frequency of 1000 Hz. The participants weren't advised of the moment of the recording to avoid any unconscious change in their moving biomechanics. Each participant wore the running shoe they typically used during running for this study. Table 3 details the biomechanical variables of interest for running.

No follow-up phase was organized since it wasn't required for the smooth operation of this study.

The spatiotemporal and kinetic parameters were calculated from the force signals recorded by the force transducers. The calculation of each parameter is detailed in the appendix.

2.2 STATISTICAL ANALYSIS

The data during this experimentation were collected on a secured computer and recorded on an excel document. All these data were secured by a password. Normality of the variable's distribution was tested by using a Shapiro-Wilk test. Then, a one-way ANOVA or a Kruskal Wallis Analysis compared the descriptive and clinical assessment variables between clinical categories. Finally, a One Way Anova or a Kruskal-Wallis Analysis compared the different biomechanical parameters between clinical categories for gait and running. The carried-out analysis compared injured limbs for Copers, CAI and LAS and to healthy limbs for controls. Post Hoc analysis was done using Holm Sidak method. All statistical analysis were performed on R(2023.12.1:402). Statistical significance was be set at $\alpha < 0.05$.

A sub-analysis was carried out following our data collection to assess the influence of gender on results and to assess the presence of biomechanical differences between groups, within males and females. A One-Way Anova Analysis compared the different running biomechanical parameters between clinical categories. Statistical significance was set at $\alpha < 0.05$.

3. RESULTS

3.1. PARTICIPANTS

A total of 150 people completed the recruitment process and 74 were enrolled in the protocol, i.e., Healthy: $n = 24$, Copers: $n = 15$, CAI: $n = 18$, LAS: $n = 17$, including 49 men and 25 women. The 76 exclusions recorded were explained by three reasons: some did not respond to the second form collecting demographic data, others did not meet the criteria, and some had organizational problems. (table 1). A one-way Anova was used to compare descriptive data clinical categories and the p-value testifies that there are no significant differences concerning groups characteristics such as the age, weight, height, and physical activity level (Tegner Scale). (Table 4)

Table 1. Descriptive data of the participants by clinical categories

	HEALTHY		COPERS		CAI		LAS		p-value
	mean (sd)	min-max	mean (sd)	min-max	mean (sd)	min-max	mean (sd)	min-max	
Age (years)	27.9 (8.65)	18 - 55	27.5 (5.13)	21 - 43	28.8 (10.25)	18 - 54	24.6 (5.71)	19 - 44	0.319
Weight (kg)	73.1 (8.87)	54.4 - 90.3	69.9 (7.47)	58.4 - 81.3	72.2 (11.98)	54.8 - 93.2	74.9 (14.53)	53.8 - 105.7	0.68
Height (cm)	178.2 (7.64)	163 - 198	173.6 (6.38)	163 - 185	177 (10.6)	160 - 193	178.9 (9.41)	157 - 190	0.285
Tegner scale	5.7 (0.72)	4 - 7	5.8 (1.05)	3 - 9	5.9 (1.27)	3 - 9	5.8 (1.26)	3 - 9	0.246

CAI : Chronic ankle instability group, LAS: Acute lateral ankle sprains group. Data are expressed in mean (standard deviation) and minimal - maximal value. A one-way ANOVA was used to compared clinical categories (pvalue).

Table 2. Descriptive data of the participants by clinical categories

	HEALTHY		COPERS		CAI		LAS		2wANOVA		
	MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD	ankle factor pvalue	group factor pvalue	interaction pvalue
FAAM (%)	99.8	0.66	97.4	4.43	97.3	4.49	97.2	4.99	0.011	0.014	0.349
FAAM sport (%)	99.7	1.09	90.8	16.59	90.5	16.82	89.0	18.65	0.014	0.002	0.291
CAIT	29.2	1.39	23.4	5.29	23.2	5.30	24.1	5.59	<0.001	<0.001	0.021
Pain (/10)	0.2	1.04	0.9	1.35	0.9	1.37	0.9	1.38	0.003	0.047	0.451
Swelling (cm)	54.3	2.98	54.5	4.77	54.7	4.80	54.2	4.09	0.412	0.863	0.91
Dorsiflexion ROM (cm)	13.9	2.91	12.8	3.38	12.8	3.45	12.5	3.25	0.752	0.769	0.925
PTGT (°)	15.8	5.09	15.6	6.21	15.5	6.23	16.1	5.56	0.412	0.446	0.332
BESS OE (n)	0.7	1.77	0.8	1.50	0.9	1.52	0.9	1.59	0.845	0.173	0.722
BESS CE (n)	9.3	1.63	9.6	1.51	9.6	1.54	9.5	1.85	0.387	0.635	0.56
YBT (composite)	87.9	5.90	86.1	5.02	86.0	4.87	86.3	5.27	0.924	0.927	0.844
SLR (°)	43.7	10.06	46.0	12.08	45.8	12.26	46.4	11.99	0.181	0.601	0.655

CAI : Chronic ankle instability group, LAS: Acute lateral ankle sprains group. Data are expressed in mean (standard deviation). A two way (ankle, i.e., injured or not, and clinical group) ANOVA was performed to assess differences.

A two-way ANOVA indicated significant effects associated with the ankle condition on the FAAM scores ($p = 0.011$), FAAM Sport scores ($p = 0.014$), CAIT scores ($p < 0.001$), and pain levels ($p = 0.003$). Additionally, significant effects were noted for the group factor on FAAM ($p = 0.014$), FAAM Sport ($p = 0.002$), CAIT ($p < 0.001$), and pain levels ($p = 0.047$). Descriptive analyses demonstrated that the Healthy group exhibited the highest scores on FAAM, FAAM Sport, and CAIT, suggesting superior foot and ankle function and stability. Conversely, the COPERS, CAI, and LAS groups displayed notably lower scores, especially in FAAM Sport and CAIT. Furthermore, pain levels were significantly elevated in the injured ankles across all clinical conditions examined. There were no significant differences in swelling and dorsiflexion ROM across the groups. Similarly, PTGT, BESS with eyes open (BESS OE) and closed (BESS CE), YBT, and SLR results were comparable, indicating no significant variations in balance and proprioceptive performance among the groups.

3.2. WALKING MECHANISM

Comparison of the biomechanical parameters that were collected during the walking analysis revealed two significant differences among the four categories. First, significant differences was shown in the mean values of recovery (Fig. 5) between categories that is thus accompanied with a slight modification of the reversed pendulum movement: 71.9% for the control subjects, 68.5% for the copers group, 70.1% for the CAI group, and 58.01% for the LAS group (Table 3). These percentages represent the amount of restituted energy between kinetic and potential energy during one stride while walking. The significant decreased percentage of LAS groups shows that they present a decreased ability to convert potential energy in kinetic energy between each stride. The LAS group also exhibited a significantly reduced step duration (Fig. 6), with the injured limb accounting for 41.31% ($p < 0.05$) of the stride, while the other three categories demonstrated symmetric step durations, with each step constituting 50% of the stride. No other significant differences were found in the walking parameters among these four categories

Table 3. Comparison of walking gait parameters between group for injured ankle

	Healthy		Copers		CAI		LAS		p-value
	Mean (sd)	min-max	Mean (sd)	min-max	Mean (sd)	min-max	Mean (sd)	min-max	
Speed (km/h)	4.65 (0.4)	4 - 5.5	4.6 (0.34)	4 - 5	4.64 (0.38)	4 - 5.5	4.56 (0.58)	4 - 6	0.85
Base of Support Width (cm)	11.83 (2.04)	9.63 - 17.62	11.72 (2.20)	6.4 - 16.24	12.6 (2.18)	8.29 - 15.91	10.4 (0.49)	7.92 - 14.31	0.62
Braking Impulse (%BW.s)	3.11 (0.12)	2.54 - 3.68	3.09 (0.2)	2.71 - 3.42	3.11 (0.19)	2.41 - 3.64	2.76 (0.28)	0.19 - 3.74	0.90
Braking Peak Force (%BW)	17.7 (0.2)	14.2 - 22.5	17.3 (0.19)	13.5 - 21.6	17.4 (0.28)	13.2 - 22.6	15.2 (0.67)	1.19 - 21.16	0.96
Cadence (spm)	110.23 (0.51)	102.7 - 120	110.89 (0.5)	101.6 - 118.8	110.11 (0.53)	96.4 - 117.4	89.99 (0.43)	93.5 - 119.2	0.59
COM Fore-Aft Displ. (mm)	20.44 (2.67)	15.5 - 24.5	20.81 (1.72)	17.8 - 23.4	21.02 (0.4)	14.9 - 29.4	19.17 (0.77)	2.45 - 25.5	0.87
COM Lateral Displ. (mm)	20.36 (0.43)	12 - 32.6	20.31 (0.42)	13.6 - 27.8	20.97 (0.44)	12.7 - 28.9	18.95 (1.04)	2.23 - 36.5	0.87
COM Path (mm)	95.59 (1.22)	72.8 - 126.9	96.53 (0.96)	76.4 - 112.3	97.13 (1.56)	74.6 - 132.9	85.97 (3.92)	4.93 - 127.5	0.98
COM Vertical Displ. (mm)	36.8 (5.99)	24.5 - 53.5	37.35 (4.43)	29.4 - 42.7	37.34 (7.74)	25.2 - 55	33.11 (1.55)	2 - 51.4	0.97
Contact Duration (%stride)	63.26 (0.84)	62 - 65	63.4 (0.74)	62 - 65	63.44 (0.98)	62 - 65	52.38 (0.25)	62 - 66	0.43
Double Support Duration (%stride)	13.26 (0.84)	12 - 15	13.4 (0.74)	12 - 15	13.44 (0.98)	11 - 15	11.16 (0.51)	12 - 16	0.43
Duty Factor	0.63 (0.01)	0.62 - 0.65	0.63 (0.01)	0.63 - 0.65	0.63 (0.01)	0.61 - 0.64	0.52 (0.25)	0.43 - 0.87	0.48
L/P Peak Ratio	1.08 (0.07)	0.96 - 1.3	1.06 (0.09)	0.96 - 1.33	1.06 (0.1)	0.95 - 1.25	0.88 (0.4)	0.25 - 1.22	0.29
Lateral Push Impulse (%BW.s)	1.93 (0.41)	1.25 - 3.2	1.97 (0.44)	1.18 - 2.8	2.07 (0.44)	1.35 - 2.89	1.7 (0.84)	0.28 - 3.16	0.50
Lateral Push Peak Force (%BW)	6.22 (0.91)	4.5 - 8.5	6.53 (1.61)	4.9 - 10.9	6.53 (1.11)	5.1 - 8.7	5.25 (2.29)	0.97 - 8.4	0.40
Lateral Strike Impulse (%BW.s)	0.18 (0.07)	0.05 - 0.26	0.17 (0.07)	0.02 - 0.28	0.16 (0.06)	0.06 - 0.25	0.17 (0.08)	0.04 - 0.33	0.74
Lateral Strike Peak Force (%BW)	4.23 (1.24)	1.8 - 6.2	4.21 (1.23)	1 - 5.4	4.01 (1.15)	2.1 - 5.5	3.79 (1.64)	1.01 - 6.5	0.72
Loading Peak Force (%BW)	114.8 (6.59)	105.6 - 131.5	115.84 (7.1)	104.9 - 130.6	112.86 (7.68)	102.1 - 133.5	96.58 (4.41)	3.77 - 121.8	0.61
Loading Rate (%BW/ms)	1.01 (0.2)	0.68 - 1.56	0.9 (0.14)	0.62 - 1.07	0.91 (0.15)	0.72 - 1.31	0.76 (0.33)	0.12 - 1.16	0.07

Mech. Work Fore-aft (J/kg.m)	0.45 (0.04)	0.38 - 0.55	0.46 (0.05)	0.35 - 0.57	0.45 (0.06)	0.36 - 0.51	0.39 (0.19)	0.01 - 0.55	0.92
Mech. Work Lateral (J/kg.m)	0.01 (0)	0.01 - 0.02	0.01 (0)	0.01 - 0.02	0.01 (0)	0 - 0.01	0.01 (0.01)	0 - 0.02	0.44
Recovery (%)	71.91 (3)	65.39 - 77.12	68.49 (4.15)	59.73 - 73.96	70.11 (2.58)	64.67 - 74.55	58.01 (2.69)	1.26 - 74.26	0.03*
Mech. Work Total (J/kg.m)	0.27 (0.04)	0.2 - 0.36	0.32 (0.06)	0.25 - 0.46	0.29 (0.04)	0.23 - 0.36	0.26 (0.13)	0.015 - 0.37	0.18
Mech. Work Vertical (J/kg.m)	0.51 (0.07)	0.36 - 0.66	0.53 (0.06)	0.43 - 0.63	0.52 (0.07)	0.39 - 0.67	0.45 (0.22)	0.018 - 0.66	0.83
Mid-Support Force (%BW)	74.02 (6.07)	53.2 - 82.5	72.38 (6.1)	59.9 - 80.7	74.41 (5.49)	61.6 - 81.8	59.22 (2.77)	1.71 - 84.4	0.08
Propulsive Impulse (%BW.s)	3.01 (0.34)	2.45 - 3.68	2.99 (0.23)	2.54 - 3.28	3.03 (0.42)	2.33 - 3.79	2.62 (1.19)	0.225 - 3.66	0.97
Propulsive Peak Force (%BW)	20.27 (1.65)	17.8 - 23.4	20.65 (2.09)	16.1 - 22.4	20.4 (2.64)	16.8 - 26.8	17.86 (0.83)	0.91 - 24.6	0.91
Push-Off Peak Force (%BW)	106.97 (4.27)	98 - 115.6	109.99 (6.2)	98.7 - 125.2	106.96 (4.96)	96.8 - 113.4	91.24 (4.22)	2.34 - 121.4	0.47
Push-Off Rate (%BW/ms)	1.18 (0.1)	0.99 - 1.43	1.22 (0.11)	1 - 1.46	1.2 (0.1)	1.08 - 1.46	1.03 (0.48)	0.041 - 1.46	0.69
Single Support Duration (%stride)	36.74 (0.84)	35 - 38	36.6 (0.74)	35 - 38	36.56 (0.98)	36 - 39	30.25 (1.41)	0.8 - 38	0.59
Step Duration (%stride)	50 (0)	50 - 50	50 (0)	50 - 50	50 (0)	50 - 50	41.31 (0.19)	0.7 - 50	0.02*
Step Length (cm)	70.31 (4.1)	61.9 - 78.5	68.62 (4.1)	62.1 - 74.3	69.77 (6.61)	55.6 - 80.7	58.73 (2.75)	57.65 - 83.5	0.80
Stride Duration (ms)	1090.85 (4.97)	999.99 - 1168.2	1084.42 (4.95)	1010.2 - 1187.2	1092.47 (5.51)	1015.6 - 1244.8	914.45 (4.37)	889.4 - 1283.3	0.84
Time to B-P Transition (%stride)	34.61 (1.39)	31.3 - 36.1	35.31 (1.06)	33.4 - 37.5	34.86 (1.3)	31.6 - 37.1	29.52 (1.35)	29.12 - 37.6	0.76
Time to Mid-Support (%stride)	31.45 (1.35)	28 - 33.7	32.37 (1.12)	31.4 - 35.2	31.68 (1.71)	28 - 34.3	26.8 (1.2)	26 - 34.6	0.43
Time to Push-Off Peak (%stride)	49.1 (0.8)	47.9 - 50.5	49.61 (0.75)	48 - 51.3	49.18 (1.01)	47.5 - 50.9	40.9 (1.9)	38.7 - 50.5	0.39
Vertical Impulse (%BW.s)	54.54 (2.54)	49.2 - 57.33	54.31 (2.5)	50.49 - 59.05	54.64 (2.76)	50.82 - 62.19	45.86 (2.16)	45 - 64.13	0.83
Walk ratio (cm/spm)	0.64 (0.05)	0.56 - 0.72	0.62 (0.05)	0.52 - 0.67	0.64 (0.08)	0.47 - 0.8	0.54 (0.26)	0.52 - 0.74	0.85

%BW = percentage of body weight; spm = steps per minute; %stride = percentage of step length; %BW.s = percentage of body weight per second; %BW/ms = percentage of body weight per millisecond; cm/spm = centimetres per step per minutes; J/kg.m = joules per kilogram per meter

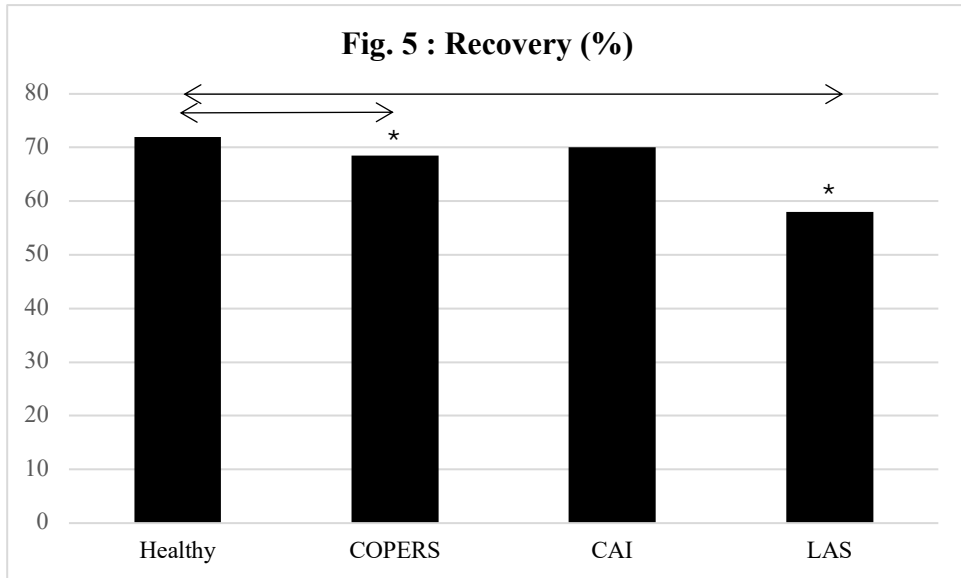


Fig. 5. Recovery measured on force platform during the walking analysis for healthy runners, copers, CAI and LAS groups. LAS group presents a significant lower result with a percentage of recovery equal to 58,01% while other groups present a result of 71.91% for the control subjects, 68.49% for the copers group, and 70.11% for the CAI group.

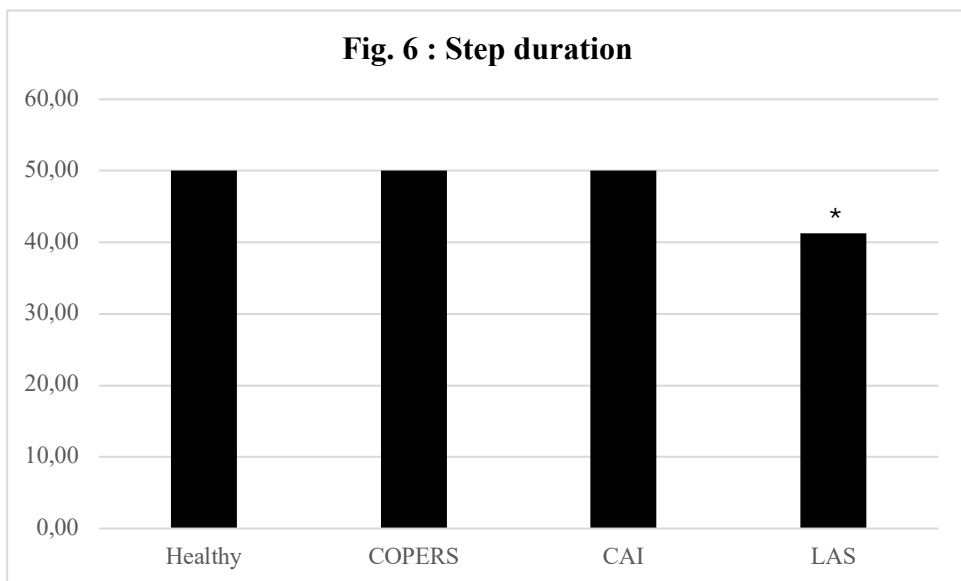


Fig. 6. Step duration measured on force platform during the walking analysis for healthy runners, copers, CAI and LAS groups. LAS group also exhibited a significantly reduced step duration, with the injured limb accounting for 41.31% ($p < 0.05$) of the stride, while the other three categories demonstrated symmetric step durations, with each step constituting 50% of the stride. No other significant differences were found in the walking parameters among these four categories.

3.3. RUNNING MECHANISMS

No significant differences were observed in the running parameters among the groups (Table 4). The similarity of key biomechanical factors between groups, such as duty factor, which represents the ratio between contact duration and stride duration, or leg stiffness, which represents the stiffness of the leg spring computed as the ratio of the maximal vertical force to the compression of the leg, support the fact that all groups run with similar biomechanics

Table 4. Comparison of running gait parameters between group for injured ankle

	Healthy		Copers		CAI		LAS		p-value
	Mean (sd)	min-max	Mean (sd)	min-max	Mean (sd)	min-max	Mean (sd)	min-max	
Active Peak Force (%BW)	234.18 (2.06)	185.3 – 266.9	233.32 (2.40)	195.7 – 280.1	231.74 (2.45)	197.8 – 285.1	239.3 (2.02)	207.1 – 278.5	0.48
Aerial Duration (%stride)	10.92 (2.93)	2.1 – 14.4	11.19 (3.31)	7 – 17.1	11.18 (3.88)	6.7 – 19.2	11.85 (2.56)	7.1 – 16.1	0.79
Base of Support Width (cm)	6.7 (2.94)	0.84 – 14.46	6.17 (1.91)	3.06 – 9.41	7.37 (2.37)	3.84 – 12.42	6.97 (2.37)	2.38 – 10.93	0.32
Braking Impulse (%BW.s)	1.84 (0.19)	1.53 – 2.32	1.83 (0.20)	1.47 – 2.232	1.85 (0.18)	1.49 – 2.12	1.8 (0.17)	1.51 – 2.15	0.59
Braking Peak Force (%BW)	27.6 (4.30)	19 – 34.8	26.5 (3.60)	21 – 33.3	26.21 (4.03)	20.7 – 36.3	27.18 (3.58)	21.5 – 33.9	0.97
Cadence (spm)	162.76 (0.64)	153.5 – 179.4	159.86 (0.54)	147.6 – 170.1	159.14 (0.86)	149 – 171.5	159.86 (0.77)	144.1 – 176.3	0.56
COM Fore-Aft Displ. (mm)	11.46 (1.45)	9.3 – 14.6	11.43 (1.43)	8.1 – 13.1	11.93 (1.57)	9.3 – 15.4	11.61 (1.64)	8.9 – 15.2	0.68
COM Lateral Displ. (mm)	6.16 (3.19)	2.6 – 15.7	5.99 (2.43)	3.9 – 11.1	7.55 (3.83)	2.4 – 17.6	7.15 (3.42)	3.4 – 14.2	0.37
COM Path (mm)	168.76 (2.09)	123.5 – 205.1	173.23 (2.11)	140.6 – 215.7	174.98 (2.49)	140.6 – 231.1	178.68 (2.06)	139.1 – 208.9	0.76
COM Vertical Displ. (mm)	82.45 (1.02)	60.4 – 100.6	84.86 (1.03)	69.1 – 105.8	85.52 (1.23)	66.8 – 101.4	87.31 (1.02)	67.8 – 102.3	0.43
Contact Duration (%stride)	39.07 (0.29)	34.8 – 47.9	38.8 (0.33)	32.9 - 43	38.81 (0.38)	30.3 – 43.3	38.14 (0.25)	33.9 – 42.9	0.56
Duty Factor	0.39 (0.03)	0.35 – 0.48	0.38 (0.03)	0.33 – 0.42	0.38 (0.04)	0.3 – 0.43	0.38 (0.03)	0.34 – 0.43	0.84
Impact Peak Force (%BW)	148.09 (17.79)	117.6 – 175.1	142.38 (18.70)	108.9 – 181.7	147.44 (22.55)	122.3 – 196.3	150.39 (21.59)	117.8 – 194.3	0.84
Lateral Push Impulse (%BW.s)	0.53 (0.40)	0.071 – 1.94	0.55 (0.30)	0.173 – 1.17	0.67 (0,34)	0,21 - 1,52	0,69 (0,32)	0,21 - 1,4	
Lateral Push Peak Force (%BW)	8.16 (3.33)	2.6 – 14.1	8.19 (3.46)	3.3 – 14.9	9.36 (2.52)	5 – 13.4	9.51 (2.32)	5 – 13.2	0.40
Lateral Strike Impulse (%BW.s)	0.19 (0.15)	0.00 – 0.59	0.20 (0.13)	0.037 – 0.47	0.14 (0.10)	0.011 – 0.344	0.17 (0.13)	0.00 – 0.56	0.37
Lateral Strike Peak Force (%BW)	7.28 (3.76)	0.3 – 17.1	8.21 (4.12)	2.2 – 14.9	7.72 (4.75)	1.6 – 19.4	8.39 (4.57)	1.7 – 16.3	0.61

Leg length (m)	0.94 (0.04)	0.86 – 1.05	0.92 (0.03)	0.86 – 0.95	0.94 (0.06)	0.85 – 1.02	0.95 (0.05)	0.81 – 1.01	0.57
Leg Stiffness (%BW/m)	1427.3 (13.91)	1149.2 – 1679.9	1545.8 (49.43)	1041.5 – 1696.2	1438.1 (22.06)	995.9 – 1911.4	1525.8 (35.48)	1151.7 – 2655.5	0.85
Loading Rate (%BW/ms)	4.45 (1.10)	2.856 – 6.65	4.42 (1.08)	2.81 – 7.38	4.84 (1.38)	2.87 – 8.29	4.80 (1.45)	3.14 – 7.3	0.63
Mech. Work Fore-aft (J/kg.m)	0.48 (0.05)	0.4 – 0.63	0.47 (0.05)	0.39 – 0.53	0.48 (0.06)	0.37 – 0.54	0.47 (0.06)	0.31 – 0.53	0.83
Mech. Work Total (J/kg.m)	1.27 (0.10)	0.99 – 1.42	1.28 (0.08)	1.11 – 1.38	1.31 (0.12)	1.12 – 1.52	1.3 (0.10)	1.14 – 1.44	0.53
Mech. Work Vertical (J/kg.m)	0.8 (0.09)	0.54 – 0.96	0.83 (0.09)	0.68 – 1.03	0.85 (0.13)	0.65 – 1.1	0.84 (0.10)	0.69 – 0.99	0.37
Propulsive Impulse (%BW.s)	1.8 (0.20)	1.49 – 2.16	1.77 (0.22)	1.27 – 2.01	1.80 (0.21)	1.35 – 2.13	1.78 (0.24)	1.18 – 2.16	0.95
Propulsive Peak Force (%BW)	21.9 (3.57)	15.7 – 25.7	20.97 (3.52)	15.1 – 25.8	21.62 (4.44)	14.1 – 30.9	21.63 (3.20)	13.4 – 28.7	0.90
Push-Off Rate (%BW/ms)	2.04 (0.37)	1.28 – 2.91	2.11 (0.45)	1.54 – 3.02	1.99 (0.51)	1.4 – 3.35	2.11 (0.31)	1.37 – 2.6	0.81
Step Length (cm)	101.68 (1.18)	79.4 – 124.2	100.29 (1.14)	84.5 – 117.1	99.42 (1.42)	79.5 – 122.9	102.49 (1.32)	81 – 126.5	0.90
Stride Duration (ms)	738.47 (2.87)	668.8 – 781.8	751.61 (2.57)	705.6 – 813.3	756.22 (4.03)	683.1 – 800.7	752.44 (3.72)	680.6 – 811.6	0.33
Time to Active Peak (%stride)	16.45 (0.19)	13.2 – 21.8	17 (0.23)	13.2 – 20.5	16.32 (0.20)	12.2 – 18.9	16.1 (0.18)	13.3 – 18.7	0.64
Time to B-P Transition (%stride)	19.39 (1.72)	16.6 – 24.1	19.34 (2.34)	15.4 – 22.4	19.34 (2.21)	14.7 – 22.7	18.85 (1.67)	16.1 – 21.4	0.84
Time to Braking Peak (%stride)	9.94 (1.88)	3.9 – 13.7	9.93 (1.67)	7.2 – 11.8	9.72 (1.46)	6 – 11.4	9.8 (1.45)	6.4 – 11.7	0.97
Time to Impact Peak (%stride)	6.39 (1.09)	4.1 – 8.6	5.97 (0.89)	3.6 – 7.3	5.96 (0.81)	4.4 – 7.4	6.08 (0.74)	4.8 – 7.5	
Time to Propulsive Peak (%stride)	28.36 (0.25)	24.6 – 35.8	28.35 (0.30)	22.7 -	28.48 (0.29)	21.9 – 32.5	27.81 (0.20)	24.9 – 31.1	0.89
Vertical Impulse (%BW.s)	36.89 (1.41)	33.29 – 39.07	37.59 (1.32)	35.16 – 40.66	37.75 (1.98)	34.15 – 40.19	37.56 (1.90)	33.5 – 41.09	0.34

%BW = percentage of body weight; spm = steps per minute; %stride = percentage of step length; %BW.s = percentage of body weight par second; %BW/ms = percentage of body weight par millisecond; cm/spm = centimetres per step per minutes; J/kg.m = joules per kilogram per meter

3.4. PARTICIPANTS CHARACTERISTICS

Concerning participants characteristics, the proportions of men and women are uneven, since there are 49 men and 25 women among our participants. A sub-analysis (Table 7 and 8) was carried out to assess gender influence on accuracy of our results since biomechanical kinetic and kinematic differences related to gender had already been demonstrated (Kearns, Z., 2024; Sakaguchi, M., 2014; Xie, P, 2022).

As regards gait analysis, there are several significant differences, especially in the CAI and COPERS categories.

Table 7. Comparison of injured ankle between men and women during the walk for each category

	HAE			COPERS			CAI			LAS		
	Mean Man	Mean Women	p-value	Mean Man	Mean Women	p-value	Mean Man	Mean Women	p-value	Mean Man	Mean Women	p-value
Base of Width (cm)	12.21	11.06	0.15	12.59	10.41	0.05	12.66	12.50	0.44	10.87	9.42	0.30
Braking Impulse (%BW.s)	3.07	3.11	0.39	3.07	3.11	0.39	3.15	3.04	0.29	2.81	2.65	0.42
Braking Peak Force (%BW)	17.64	17.68	0.48	16.77	18.05	0.13	17.33	17.53	0.44	15.34	14.86	0.45
Cadence (spm)	109.55	111.60	0.19	110.01	112.22	0.23	108.41	113.50	0.02*	90.47	88.85	0.48
COM Fore-Eft Displ. (mm)	20.77	19.79	0.22	20.92	20.63	0.38	21.52	20.02	0.19	20.04	17.09	0.26
COM Path (mm)	98.43	89.91	0.06	99.41	92.20	0.10	100.56	90.28	0.10	90.65	74.77	0.24
COM Vertical Displ. (mm)	38.33	33.75	0.04*	38.79	35.18	0.08	39.37	33.28	0.04*	35.12	25.76	0.17
Contact duration (%stride)	63.26	63.25	0.49	63.67	63.00	0.04*	63.50	63.33	0.36	52.79	51.38	0.46
Double Support Duration (%stride)	13.26	13.25	0.49	13.67	13.00	0.04*	13.50	13.33	0.36	11.10	11.28	0.48
Duty Factor	0.63	0.63	0.40	0.64	0.63	0.06	0.63	0.51	0.20	0.53	0.51	0.46
L/P Peak Ratio	1.08	1.06	0.19	1.05	1.06	0.43	1.04	1.10	0.16	0.91	0.81	0.34
Lateral Push Impulse (%BW.s)	1.92	1.96	0.43	2.03	1.88	0.28	1.94	2.35	0.02*	1.67	1.78	0.41
Lateral Push Peak Force (%BW)	6.18	6.30	0.39	6.20	7.02	0.39	6.09	7.40	0.01*	5.22	5.33	0.47
Lateral Strike Impulse (%BW.s)	0.19	0.16	0.19	0.17	0.18	0.43	0.19	0.12	0.00*	0.17	0.16	0.45
Lateral Strike Peak Force (%BW)	4.43	3.81	0.10	4.24	4.15	0.44	4.38	3.27	0.02*	3.93	3.46	0.30
Loading Peak Force (%BW)	115.74	112.93	0.12	116.20	115.30	0.42	112.12	114.35	0.26	100.15	85.19	0.32
Loading Rate (%BW/ms)	1.01	1.03	0.41	0.88	0.92	0.32	0.93	0.88	0.22	0.78	0.72	0.37
Mech. Work Fore-Aft (J/kg.m)	0.45	0.45	0.39	0.45	0.47	0.23	0.45	0.46	0.33	0.41	0.36	0.33

Mech. Work Lateral (J/kg.m)	0.01	0.01	0.36	0.01	0.01	0.48	0.01	0.01	0.16	0.01	0.01	0.33
Recovery (%)	71.52	72.69	0.19	70.34	67.23	0.11	70.34	69.66	0.34	58.47	56.92	0.46
Mech. Work Total (J/kg.m)	0.28	0.26	0.09	0.31	0.33	0.32	0.29	0.30	0.40	0.27	0.23	0.29
Mech. Work Vert. (J/kg.m)	0.53	0.48	0.05	0.55	0.50	0.05	0.53	0.51	0.26	0.47	0.41	0.32
Mid-Support Force (%BW)	73.13	75.81	0.12	71.90	73.10	0.37	73.90	75.42	0.27	60.40	75.42	0.19
Propulsive impulse (%BW.s)	3.03	2.98	0.37	2.96	3.04	0.30	3.06	2.96	0.30	2.40	2.40	0.50
Propulsive Peak Force (%BW)	20.24	20.34	0.45	20.16	21.38	0.14	20.24	20.72	0.34	18.42	16.52	0.35
Push-Off Peak Force (%BW)	107.02	106.86	0.47	110.44	109.32	0.39	107.88	105.10	0.22	92.63	87.91	0.43
Push-Off Rate (%BW/ms)	1.17	1.21	0.20	1.20	1.26	0.19	1.19	1.22	0.25	1.04	1.00	0.45
Single Support Duration (%stride)	36.74	36.75	0.49	36.33	37.00	0.04*	36.50	36.67	0.36	30.78	28.99	0.42
Step Duration (%stride)	50.00	50.00	0.50	50.00	50.00	0.50	50.00	50.00	0.50	50.00	50.00	0.50
Step Length (cm)	71.17	68.59	0.10	68.76	68.42	0.44	72.62	64.07	0.00*	60.80	53.76	0.33
Time to B-P Transition (%stride)	34.78	34.28	0.24	35.44	35.10	0.26	34.79	34.98	0.35	29.79	28.89	0.46
Time to Mid-Support (%stride)	31.30	31.74	0.23	32.13	32.72	0.19	31.05	32.93	0.03*	27.00	26.31	0.46
Time to Push-off Peak (%stride)	49.11	49.08	0.47	49.11	49.37	0.24	49.16	49.23	0.44	41.35	39.83	0.45
Vertical Impulse (%BW.s)	54.79	54.05	0.26	54.76	53.63	0.22	55.48	52.95	0.02*	46.71	43.83	0.41
Walk Ratio (cm/spm)	0.65	0.62	0.09	0.63	0.61	0.32	0.67	0.57	0.00*	0.56	0.49	0.31

%BW = percentage of body weight; spm = steps per minute; %stride = percentage of step length; %BW.s = percentage of body weight per second; %BW/ms = percentage of body weight per millisecond; cm/spm = centimetres per step per minutes; J/kg.m = joules per kilogram per meter

Table 8. Comparison of injured ankle between men and women during the run for each category

	HAE			COPERS			CAI			LAS		
	Mean Man	Mean Women	p-value	Mean Man	Mean Women	p-value	Mean Man	Mean Women	p-value	Mean Man	Mean Women	p-value
Active Peak Force (%BW)	244.40	221.83	0.04*	236.52	241.88	0.31	226.86	235.00	0.29	232.58	235.52	0.37
Aerial Duration (%stride)	12.09	10.39	0.18	12.04	11.38	0.34	10.09	11.20	0.33	11.07	11.62	0.33
Base of Support Width (cm)	6.50	6.27	0.41	5.95	8.28	0.05	7.35	6.01	0.22	7.17	7.41	0.44
Braking Impulse (%BW.s)	1.76	1.95	0.02*	1.88	1.78	0.23	1.82	1.91	0.27	1.84	1.85	0.44
Braking Peak Force (%BW)	27.29	27.03	0.44	27.27	26.70	0.42	26.01	30.08	0.10	26.40	25.96	0.39
Cadence (spm)	161.64	159.40	0.20	163.89	157.40	0.14	160.86	162.16	0.42	158.41	160.42	0.27
COM Fore-Aft Displ. (mm)	11.18	12.20	0.09	11.66	11.38	0.39	11.39	12.08	0.32	11.74	11.84	0.44
COM Lateral Displ. (mm)	5.28	7.59	0.07	5.11	8.08	0.07	7.86	6.48	0.28	6.65	8.56	0.17
COM Path (mm)	177.98	166.73	0.19	169.52	184.00	0.12	166.33	170.50	0.36	176.79	177.10	0.49
COM Vertical Displ. (mm)	87.28	81.13	0.17	82.86	90.06	0.12	81.26	83.08	0.37	86.57	86.40	0.49
Contact duration (%stride)	37.91	39.61	0.18	37.96	38.62	0.34	39.91	38.80	0.33	38.93	38.38	0.33
Duty Factor	0.38	0.40	0.18	0.38	0.39	0.34	0.40	0.39	0.33	0.39	0.38	0.33
Impact Peak Force (%BW)	144.30	144.18	0.50	153.95	140.84	0.09	145.63	146.06	0.49	149.74	151.48	0.44
Lateral Push Impulse (%BW.s)	0.48	0.76	0.05	0.41	0.73	0.04*	0.72	0.48	0.14	0.67	0.65	0.47
Lateral Push Peak Force (%BW)	8.28	9.73	0.14	7.63	10.22	0.06	9.80	6.64	0.02*	8.73	8.92	0.46
Lateral Strike Impulse (%BW.s)	0.23	0.20	0.32	0.20	0.14	0.18	0.16	0.15	0.47	0.13	0.21	0.25

Lateral Strike Peak Force (%BW)	8.83	8.85	0.50	8.52	7.02	0.25	7.87	7.66	0.48	5.96	7.06	0.31
Leg Stiffness (%BW/m)	1496	1356	0.0741	1468.4	1454.6	0.41	1547	1406.9	0.2621	1403	1719.8	0.14
Loading Rate (%BW/ms)	4.56	4.65	0.41	4.66	4.67	0.50	4.84	5.03	0.42	4.58	3.71	0.07
Mech. Work Fore-Aft (J/kg.m)	0.47	0.49	0.15	0.50	0.44	0.06	0.47	0.51	0.12	0.48	0.49	0.30
Mech. Work Total (J/kg.m)	1.30	1.25	0.21	1.28	1.29	0.44	1.27	1.25	0.39	1.31	1.35	0.19
Mech. Work Vertical (J/kg.m)	0.84	0.79	0.09	0.80	0.87	0.13	0.82	0.76	0.16	0.85	0.88	0.29
Propulsive Impulse (%BW.s)	1.75	1.85	0.12	1.85	1.66	0.09	1.74	1.88	0.23	1.81	1.83	0.40
Propulsive Peak Force (%BW)	21.58	21.99	0.40	23.00	19.80	0.11	20.15	22.70	0.20	21.76	22.00	0.43
Push-Off Rate (%BW/ms)	2.21	1.98	0.15	2.20	1.94	0.11	1.83	2.13	0.21	2.02	2.17	0.16
Step Length (cm)	101.60	101.15	0.47	102.34	101.68	0.45	98.21	108.26	0.13	100.40	97.16	0.33
Stride Duration (ms)	743.53	753.90	0.21	732.50	765.70	0.12	747.41	744.08	0.46	759.18	748.86	0.26
Time to Active Peak (%stride)	15.87	17.56	0.05*	16.07	15.10	0.17	16.73	16.68	0.48	16.77	16.96	0.40
Time to B-P Transition (%stride)	18.83	20.05	0.15	18.50	19.02	0.33	19.75	19.22	0.35	19.43	19.26	0.41
Time to Braking Peak (%stride)	9.64	10.23	0.26	9.40	9.16	0.37	10.38	10.40	0.49	10.22	8.76	0.16
Time to Impact Peak (%stride)	5.87	6.13	0.26	6.34	5.54	0.07	6.12	5.96	0.38	6.34	6.96	0.17
Time to Propulsive Peak (%stride)	27.39	29.40	0.08	27.39	27.96	0.32	29.16	28.32	0.33	28.50	28.34	0.44
Vertical Impulse (%BW.s)	37.13	37.80	0.15	36.60	38.11	0.14	37.33	37.03	0.42	37.94	37.43	0.26

%BW = percentage of body weight; spm = steps per minute; %stride = percentage of step length; %BW.s = percentage of body weight per second; %BW/ms = percentage of body weight per millisecond; cm/spm = centimetres per step per minutes; J/kg.m = joules per kilogram per meter

In a second step, we decided to compare the four male categories with each other and the four female categories with each other (table 9 and 10). The significant differences we found when the genders were mixed disappeared. A heterogeneous sample resulted in different results than if we had only a female or male sample.

Table 9. Comparison of injured ankle between each category for men and women separately, during the walk (ANOVA)

	Men					Women				
	HAE	COPERS	CAI	LAS	p-value	HAE	COPERS	CAI	LAS	p-value
Base of Width (cm)	12.21	12.59	12.66	10.87	0.47	11.06	10.41	12.50	9.42	0.40
Braking Impulse (%BW.s)	3.12	3.07	3.15	2.81	0.53	3.09	3.11	3.04	2.65	0.65
Braking Peak Force (%BW)	17.64	16.77	17.33	15.34	0.43	17.68	18.05	17.53	14.86	0.55
Cadence (spm)	109.55	110.01	108.41	90.47	0.08	111.60	112.22	113.50	88.85	0.24
COM Fore-Eft Displ. (mm)	20.77	20.92	21.52	20.04	0.89	19.79	20.63	20.02	17.09	0.56
COM Path (mm)	98.43	99.41	100.56	90.65	0.71	89.91	92.20	90.28	74.77	0.46
COM Vertical Displ. (mm)	38.33	38.79	39.37	35.12	0.72	33.75	35.18	33.28	25.76	0.27
Contact duration (%stride)	63.26	63.67	63.50	52.79	0.08	63.25	63.00	63.33	51.38	0.33
Double Support Duration (%stride)	13.26	13.67	13.50	11.10	0.07	13.25	13.00	13.33	11.28	0.60
Duty Factor	0.63	0.64	0.63	0.53	0.09	0.63	0.63	0.51	0.51	0.49
L/P Peak Ratio	1.08	1.05	1.04	0.91	0.18	1.06	1.06	1.10	0.81	0.13
Lateral Push Impulse (%BW.s)	1.92	2.03	1.94	1.67	0.40	1.96	1.88	2.35	1.78	0.43
Lateral Push Peak Force (%BW)	6.18	6.20	6.09	5.22	0.25	6.30	7.02	7.40	5.33	0.26
Lateral Strike Impulse (%BW.s)	0.19	0.17	0.19	0.17	0.85	0.16	0.18	0.12	0.16	0.40
Lateral Strike Peak Force (%BW)	4.43	4.24	4.38	3.93	0.80	3.81	4.15	3.27	3.46	0.52
Loading Peak Force (%BW)	115.74	116.20	112.12	100.15	0.29	112.93	115.30	114.35	85.19	0.15
Loading Rate (%BW/ms)	1.01	0.88	0.93	0.78	0.07	1.03	0.92	0.88	0.72	0.17

Mech. Work Fore-Aft (J/kg.m)	0.45	0.45	0.45	0.41	0.63	0.45	0.47	0.46	0.36	0.27
Mech. Work Lateral (J/kg.m)	0.01	0.01	0.01	0.01	0.44	0.01	0.01	0.01	0.01	0.90
Recovery (%)	71.52	70.34	70.34	58.47	0.05*	72.69	67.23	69.66	56.92	0.29
Mech. Work Total (J/kg.m)	0.28	0.31	0.29	0.27	0.69	0.26	0.33	0.30	0.23	0.19
Mech. Work Vert. (J/kg.m)	0.53	0.55	0.53	0.47	0.44	0.48	0.50	0.51	0.41	0.48
Mid-Support Force (%BW)	73.13	71.90	73.90	58.72	0.04*	75.81	73.10	75.42	60.40	0.32
Propulsive impulse (%BW.s)	3.03	2.96	3.06	2.40	0.12	2.98	3.04	2.96	2.40	0.33
Propulsive Peak Force (%BW)	20.24	20.16	20.24	18.42	0.70	20.34	21.38	20.72	16.52	0.29
Push-Off Peak Force (%BW)	107.02	110.44	107.88	92.63	0.18	106.86	109.32	105.10	87.91	0.39
Push-Off Rate (%BW/ms)	1.17	1.20	1.19	1.04	0.37	1.21	1.26	1.22	1.00	0.39
Single Support Duration (%stride)	36.74	36.33	36.50	30.78	0.12	36.75	37.00	36.67	28.99	0.20
Step Duration (%stride)	50.00	50.00	50.00	41.78	0.09	50.00	50.00	50.00	40.17	0.27
Step Length (cm)	71.17	68.76	72.62	60.80	0.18	68.59	68.42	64.07	53.76	0.25
Stride Duration (ms)	1097.54	1092.63	1109.43	931.31	0.16	1077.48	1072.10	1058.55	873.97	0.37
Time to B-P Transition (%stride)	34.78	35.44	34.79	29.79	0.16	34.28	35.10	34.98	28.89	0.41
Time to Mid-Support (%stride)	31.30	32.13	31.05	27.00	0.17	31.74	32.72	32.93	26.31	0.31
Time to Push-off Peak (%stride)	49.11	49.11	49.16	41.35	0.07	49.08	49.37	49.23	39.83	0.30
Vertical Impulse (%BW.s)	54.79	54.76	55.48	46.71	0.17	54.05	53.63	52.95	43.83	0.36
Walk Ratio (cm/spm)	0.65	0.63	0.67	0.56	0.23	0.62	0.61	0.57	0.49	0.35

%BW = percentage of body weight; spm = steps per minute; %stride = percentage of step length; %BW.s = percentage of body weight per second; %BW/ms = percentage of body weight per millisecond; cm/spm = centimetres per step per minutes; J/kg.m = joules per kilogram per meter

Table 10. Comparison of injured ankle between each category for men and women separately, during the run (ANOVA)

	Men					Women				
	HAE	COPERS	CAI	LAS	p-value	HAE	COPERS	CAI	LAS	p-value
Active Peak Force (%BW)	244.40	236.52	226.86	232.58	0.16	221.83	241.88	235.00	235.52	0.51
Aerial Duration (%stride)	12.09	12.04	10.09	11.07	0.27	10.39	11.38	11.20	11.62	0.94
Base of Support Width (cm)	6.50	5.95	7.35	7.17	0.52	6.27	8.28	6.01	7.41	0.52
Braking Impulse (%BW.s)	1.76	1.88	1.82	1.84	0.35	1.95	1.78	1.91	1.85	0.59
Braking Peak Force (%BW)	27.29	27.27	26.01	26.40	0.79	27.03	26.70	30.08	25.96	0.47
Cadence (spm)	161.64	163.89	160.86	158.41	0.28	159.40	157.40	162.16	160.42	0.86
COM Fore-Aft Displ. (mm)	11.18	11.66	11.39	11.74	0.69	12.20	11.38	12.08	11.84	0.90
COM Lateral Displ. (mm)	5.28	5.11	7.86	6.65	0.08	7.59	8.08	6.48	8.56	0.84
COM Path (mm)	177.98	169.52	166.33	176.79	0.45	166.73	184.00	170.50	177.10	0.64
COM Vertical Displ. (mm)	87.28	82.86	81.26	86.57	0.40	81.13	90.06	83.08	86.40	0.60
Contact duration (%stride)	37.91	37.96	39.91	38.93	0.27	39.61	38.62	38.80	38.38	0.94
Duty Factor	0.38	0.38	0.40	0.39	0.27	0.40	0.39	0.39	0.38	0.94
Impact Peak Force (%BW)	144.30	153.95	145.63	149.74	0.65	144.18	140.84	146.06	151.48	0.91
Lateral Push Impulse (%BW.s)	0.48	0.41	0.72	0.67	0.08	0.76	0.73	0.48	0.65	0.63
Lateral Push Peak Force (%BW)	8.28	7.63	9.80	8.73	0.38	9.73	10.22	6.64	8.92	0.26
Lateral Strike Impulse (%BW.s)	0.23	0.20	0.16	0.13	0.16	0.22	0.09	0.11	0.26	0.31

Lateral Strike Peak Force (%BW)	8.83	8.52	7.87	5.96	0.26	8.85	7.02	7.66	7.06	0.90
Leg Stifness (%BW/m)	1496.03	1468.36	1547.03	1402.97	0.70	1356.03	1454.56	1406.88	1719.82	0.30
Loading Rate (%BW/ms)	4.56	4.66	4.84	4.58	0.94	4.65	4.67	5.03	3.71	0.38
Mech. Work Fore-Aft (J/kg.m)	0.47	0.50	0.47	0.48	0.44	0.49	0.44	0.51	0.49	0.21
Mech. Work Total (J/kg.m)	1.30	1.28	1.27	1.31	0.78	1.25	1.29	1.25	1.35	0.41
Mech. Work Vertical (J/kg.m)	0.84	0.80	0.82	0.85	0.61	0.79	0.87	0.76	0.88	0.18
Propulsive Impulse (%BW.s)	1.75	1.85	1.74	1.81	0.52	1.85	1.66	1.88	1.83	0.50
Propulsive Peak Force (%BW)	21.58	23.00	20.15	21.76	0.32	21.99	19.80	22.70	22.00	0.72
Push-Off Rate (%BW/ms)	2.21	2.20	1.83	2.02	0.03*	1.98	1.94	2.13	2.17	0.86
Step Length (cm)	101.60	102.34	98.21	100.40	0.86	101.15	101.68	108.26	97.16	0.66
Stride Duration (ms)	743.53	732.50	747.41	759.18	0.22	753.90	765.70	744.08	748.86	0.87
Time to Active Peak (%stride)	15.87	16.07	16.73	16.77	0.53	17.56	15.10	16.68	16.96	0.25
Time to B-P Transition (%stride)	18.83	18.50	19.75	19.43	0.33	20.05	19.02	19.22	19.26	0.87
Time to Braking Peak (%stride)	9.64	9.40	10.38	10.22	0.26	10.23	9.16	10.40	8.76	0.53
Time to Impact Peak (%stride)	5.87	6.34	6.12	6.34	0.53	6.13	5.54	5.96	6.96	0.15
Time to Propulsive Peak %stride)	27.39	27.39	29.16	28.50	0.19	29.40	27.96	28.32	28.34	0.83
Vertical Impulse (%BW.m)	37.13	36.60	37.33	37.94	0.22	37.80	38.11	37.03	37.43	0.86

%BW = percentage of body weight; spm = steps per minute; %stride = percentage of step length; %BW.s = percentage of body weight par second; %BW/ms = percentage of body weight par millisecond; cm/spm = centimetres per step per minutes; J/kg.m = joules per kilogram per meter

4. DISCUSSION

To the best of our knowledge, this is the first study to compare gait between all four clinical categories of ankle sprains. Summarizing the major results, there is differences in the recovery and step duration between groups for the walking analysis, but no differences were highlighted for the running biomechanical parameters.

4.1. RESULTS INTERPRETATION

This is the first study to observe gait across the complete clinical spectrum of ankle sprains. Previous studies have typically focused on only two categories, while we investigated ankle-foot walking and running in four distinct categories (HEA, Copers, CAI, LAS). In 2021, Zahra Raeisi recruited 28 female university athletes, dividing in two equal groups: ankle-sprain copers (14) and healthy runners (14). They performed gait cycle analysis on a 10m path using a plantar scanning device and a force plate in the middle. The spatiotemporal parameters analyzed included the center of pressure gait line, contact time and components of vertical ground reaction forces. The results showed no significant differences between the groups and within the copers group (injured and healthy feet) for contact time or center of pressure gait line during walking. There were also no significant differences in the walking gait line between groups. Significant differences were found in the components of the vertical ground reaction force, specifically in the values of the first and second vGRF peaks and the minimum vGRF force for the intra-group comparison within copers. However, significant difference was found in the values of the time to reach the first, second vGRF, and minimum force vGRF for the intra-group comparison. Finally, there were no significant differences between groups for the first and second vGRF, but differences were found for the minimum vGRF force.

These findings are intriguing and merit comparison with our own research. It is important to note, however, that the study was limited to only two of the four categories within the clinical spectrum of ankle sprains. Additionally, in 2016, Bigouette et al. conducted a study involving 24 experienced college-aged runners, which was divided into two groups: healthy runners (13) and CAI runners (11).

Their objective was to analyze differences in the components of vertical ground reaction forces during running. For this purpose, data were collected using an instrumented treadmill and subsequently analyzed. The results indicated that the CAI group exhibited higher impact peak forces and an increased loading rate compared to the healthy runners. It was also observed that the CAI group reached the active peak force in a shorter duration than the control group, although there were no significant differences in the time required to reach the impact peak force.

Runners exhibit different ankle-foot mechanics while walking, yet similar mechanics during running, contingent upon their clinical history. This observation is likely due to the selection of individuals with minor deficits, who closely resemble typical patients encountered in clinical practice. It is important to note that biomechanical deficits are not solely attributable to ankle sprains and chronic ankle instability, as their absence cannot merely be explained by the lack of damage or injury. According to Melanson (2023), CAI does not correlate directly with the severity of the initial injury, or the treatment received. This suggests that even low-grade ankle sprains, characterized as 'stretching of the stabilizing ligaments,' can result in chronic ankle instability comparable to that caused by higher-grade injuries, which compromise syndesmotic structures. Wenning (2023) identified three key factors influencing chronic ankle instability. The first factor, mechanical ankle instability (MAI), also known as laxity, is defined by ankle movement exceeding the physiological range of motion. This condition is challenging to evaluate clinically, with physical examination remaining the preferred method, despite its lack of quantitative data. The second factor, functional ankle instability (FAI), involves the inability to control foot movement, often reported by patients as their foot 'giving way.' Freeman (1965) first described this condition, which is characterized by a normal joint range of motion that surpasses volitional control. This instability often results from repeated symptomatic ankle sprains or neuromuscular impairments affecting proprioception (Tropp, 2002). Importantly, FAI and MAI are not necessarily interconnected, as FAI may occur without MAI (Kaminski, 2002). The third factor, perceived ankle instability, reflects the subjective perception of instability, influenced by both MAI and FAI. This subjective factor was crucial in our classification process, as participants were

categorized based on their history of lateral ankle sprains and responses to subjective questionnaires.

Several studies, including those by Doherty in 2016, have investigated biomechanical parameters in running, but few have employed the same variables as our study, and many have focused on kinematics, which we did not assess, making direct comparisons difficult. Doherty's first study involved 89 participants, categorized as either copers or having CAI (69) and controls (20), recruited two weeks post-injury to analyze gait biomechanics six months later. Participants, who were instrumented with the Codamotion bilateral lower limb gait setup synchronized with force plates, walked barefoot on a 10m walkway focusing on a distant mark. This study mainly assessed kinematic parameters like hip, knee, and ankle angles at heel-strike, toe-off, and displacement, along with kinetic parameters such as joint moments. It found a significantly more flexed knee angle at heel-strike in CAI participants than in controls, greater hip extension at take-off in CAI compared to both copers and controls, and a greater maximum internal knee extension moment in CAI participants. However, spatiotemporal parameters, central to our study, were not examined. In a subsequent study within the same year, Doherty analyzed 28 CAI participants and 44 LAS copers 12 months post-injury, using three Codamotion cx 1 units and two force plates to measure time-averaged angular displacement and moments of force during specified gait periods, and ankle joint moments in the frontal plane. Their results indicated an increased bilateral hip flexion during the first period and decreased hip extension, increased knee flexion, and ankle inversion in the second period for CAI participants. Again, spatiotemporal parameters were omitted from the analysis, limiting direct comparisons with our study. Furthermore, variability in participant categorization and study conditions across different research, such as the criteria used by Liu, X., et al. (2022) to define CAI patients, complicates comparisons further. Liu's criteria included grade III injuries without bone fracture, a history of multiple sprains requiring surgery, a recent sprain at least three months prior to assessment, and participants aged 18 to 40 years, highlighting the challenges in aligning study methodologies and findings.

In 2020, Colapietro studied running mechanics over 1600 meters on a track with young women categorized as HEA (n=9) or CAI (n=9), using RunScribe pod. They

founded longer contact and cycle times in the CAI group during slow-speed trials, though no significant differences were found in step duration, which consistently represented 50% of the stride across both groups. Colapietro suggested that the prolonged contact time in the CAI group might be related to subconscious efforts to optimize postural control and the similarity of gait parameters between clinical conditions could be attributed to the procedure familiarization.

This concept of familiarization aligns with Lavcanska's findings, which indicated that a 6-minute warm-up was sufficient for treadmill running familiarization in young adults, showing no significant changes in biomechanical parameters during this period. Notably, their study was conducted on an athletic track rather than a treadmill, where running parameters might differ. For instance, treadmill running has been associated with decreased Propulsive Peak Force, knee flexion range, sagittal foot-ground angle, and vertical displacement of the center of mass (Van Hooren, 2020). These observations coincide with Riley's 2018 findings that treadmill running may lead to shorter stride lengths and higher vertical oscillation compared to overground running. Similarly, Tao H. (2019) observed increased symmetry in treadmill running compared to overground in a study of student athletes following a 15-minute warm-up. This body of research suggests that running environment significantly influences biomechanical outcomes.

Our study observed a decrease in step duration during walking, a finding consistent with Lin et al. (2021), who compared runners with chronic ankle instability (CAI) (n=13) to a control group (n=13) on a treadmill. The methodology of classifying participants using FAAM, CAIT, and clinical examination was similar to ours. Lin et al. reported early activation of leg muscles (rectus femoris, biceps femoris, and gluteus medius) during the oscillatory phase, which contributed to reduced step duration among runners with CAI. Further supporting this, Yousefi's 2023 meta-analysis revealed early activation of the soleus muscle in the CAI group, which aids in stabilizing the ankle at push-off and reducing injury risk and compensates for the diminished ankle recovery often observed in CAI patients. Similarly, Chan L.'s 2022 systematic review identified decreased activity of the long fibular muscle in individuals with ankle sprains during a one-legged jump test, suggesting a deficiency in recovery mechanisms. Complementarily, Feger (2015) observed prolonged activation of the long fibular muscle in walking among individuals with

chronic ankle instability, using a treadmill setup with electrodes on the leg and gluteal muscles. His findings indicated prolonged muscle activation but no differences in electromyographic amplitude during the pre-initial and post-initial phases. Additionally, Liu (2022) reported micro-adjustments in ankle-injury patients during walking, noting shorter stride durations and lengths. Although stride length differences were not significant in our study, these findings underline potential adaptations to prevent pain mechanisms triggered shortly after an ankle sprain. This collective research suggests that biomechanical alterations in CAI patients may serve protective or compensatory roles, impacting gait characteristics fundamentally.

To the best of our knowledge, no published studies have identified a decrease in recovery for patients with lateral ankle sprains (LAS) during walking. However, this difference can be understood when comparing it to our second significant finding. The reduced step duration observed in LAS patients results in an increased duration for the healthy limb, leading to an uneven walking pattern that can be classified as a subtle limp. The injured limb demonstrates a slightly different movement pattern, with altered muscle activation and a deficit in isometric plantarflexion, inversion, and eversion strengths that are typically seen in the first few weeks following the injury (Konradsen, 1998). This deficit impairs the ability to generate normal force during walking. Consequently, the body expends more energy to compensate for the lack of force produced by the injured limb. This increased energy consumption during walking ultimately results in a reduction in the mechanical work that can be recovered.

Our analysis did not yield many significant overall results, but notable differences emerged in our gender-based sub-analysis. Drawing on Moran's 2018 findings, women typically exhibit larger knee valgus, increased hip adduction, and greater foot pronation compared to men, potentially increasing their injury risk. Lynch (2010) had previously attributed such biomechanical disparities to anatomical differences such as leg length, weight, and joint dimensions, which vary between genders. These studies underscore why our sub-analyses, which compare men and women separately within each category, revealed more significant differences:

In Healthy individuals, men demonstrated higher active peak forces but smaller braking impulses and shorter times to active peak. In Copers, the primary difference was a higher lateral push impulse in women while CAI men showed larger lateral push peak forces, a factor that Kwon (2020) links to external tibia rotation, comparing chronic ankle instability in runners and controls.

Concerning Rehabilitation process, Brison (2019) founded no significant biomechanical differences between rehabilitated and non-rehabilitated subjects. Delahunt (2021) identified only the time to return to sport as significantly different, a factor our study did not explore. The broad categorization of sprain grades in our study—from minimal to severe impacts—might have diluted discernible results. Additionally, while clinical evidence suggests that runners can resume running without limping sooner than they can walk limp-free, our study found no significant differences in biomechanics between running and walking. This may be due to the elastic energy recovery during running, which compensates for reduced muscular activity, facilitating a smooth running gait despite varied biomechanical demands.

4.2. LIMITS OF THE STUDY

A primary limitation of our study was that categorization relied exclusively on patients' responses to two questionnaires: the FAAM (ADL subscale and sport subscale) and the CAIT. Martin (2005) established that the FAAM is a reliable, responsive, and valid measure for assessing physical function in individuals with a variety of musculoskeletal disorders of the lower leg, foot, and ankle. Similarly, Hiller (2006) confirmed that the CAIT is a simple, valid, and reliable tool for measuring the severity of functional ankle instability. However, clinical experiences suggest that individuals often overestimate their abilities when responding to questionnaires. Therefore, we cannot entirely rely on their self-reported answers. Additionally, individuals tend to unconsciously avoid physical activities that provoke instability, which might lead CAI patients to report no instability if they have ceased engaging in activities that trigger such symptoms.

Furthermore, no specific training guidelines were provided to participants prior to their appointment for physical and biomechanical assessments. It is known that

some participants engaged in training on the day of their evaluation, although they represent a small fraction of the total number of participants. This lack of standardized pre-assessment conditions could potentially influence the outcomes of our findings.

4.3. IMPLICATION FOR PHYSIOTHERAPY MANAGEMENT

The differences observed in walking mechanics should be carefully considered by physiotherapists during rehabilitation. Notably, recovery and step duration are reduced in patients with LAS and CAI. We recommend that rehabilitation efforts focus on the loading of the injured limb, supporting transfers, and improvements in the walking scheme. Specific areas for improvement should include heel strike patterns, dorsiflexion and plantarflexion range of motion, and step height, among other parameters. It is important to note that disparities in step duration were only observed in the LAS group. Since none of the participants in the CAI and Copers groups underwent physiotherapist-led rehabilitation, we cannot definitively assert that such rehabilitation is crucial for correcting this deficit. However, clinical observations suggest that focusing on these aspects is beneficial, particularly as LAS patients often exhibit impaired walking schemes early in their rehabilitation. Targeted physiotherapy could expediently and effectively reduce these deficits. Additionally, correcting the walking scheme would likely enhance the recovery and should be coupled with comprehensive recovery of ankle movement amplitudes, as well as progressive re-loading and muscle strengthening. Regarding running mechanics, we cannot draw definitive conclusions from our results, as no significant differences were observed.

4.4. OPENINGS FOR FURTHER STUDIES

Our study assessed biomechanical parameters at an easy pace, rated as 3/10 on the Rate of Perceived Exertion scale. Future research could benefit from examining biomechanical changes associated with accelerated running and corresponding increases on the RPE scale.

Additionally, considering the degrees of sprains when classifying participants could yield more nuanced insights. Currently, mixing low-affected with high-affected subjects in the CAI, LAS, and COPERS categories may contribute to the observed lack of significant findings. A more detailed classification based on the severity of sprains might reveal significant biomechanical deficits among these groups, potentially improving the management of ankle sprains.

While no significant differences were observed in running mechanics within the brief five-minute running period of our study, we recommend further research with extended running durations. This would allow for the investigation of fatigue and pre-fatigue effects on running biomechanics. Studies suggest that fatigue can accentuate certain biomechanical parameters, such as leg stiffness, knee flexion, peak acceleration, and vertical center of mass displacement (Zandbergen M., 2023; Winter S., 2017). An extended analysis period could therefore potentially reveal significant differences.

5. CONCLUSION

In conclusion, our study identified that individuals with lateral ankle sprain exhibited decreased recovery and reduced step duration as a percentage of the overall stride, compared to healthy runners, Copers, and those with chronic ankle instability. These findings are critical for physiotherapy management, as the shortened step duration observed in injured individuals may represent a protective strategy to minimize loading on the injured limb during walking, potentially leading to compensatory biomechanics in the contralateral limb. Additionally, the reduced recovery may indicate compromised motion economy, which could further contribute to altered biomechanics. Future research should explore additional factors that might influence biomechanical changes in this population.

6. REFERENCES

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7. ANNEXES

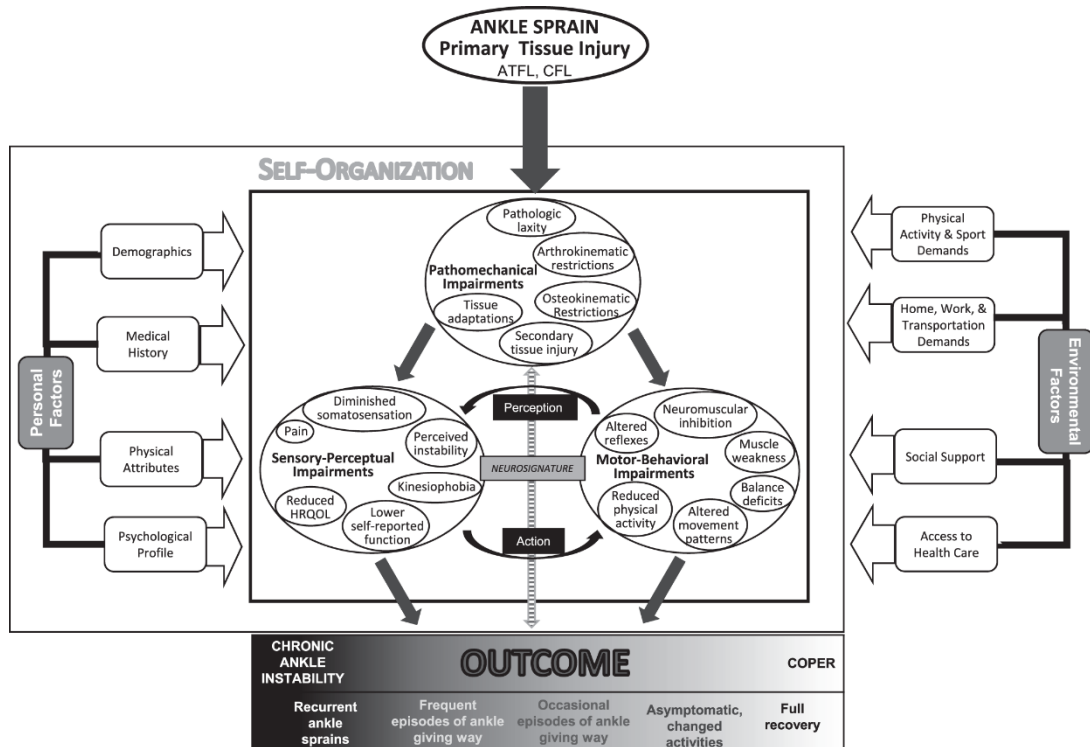


Fig 1. The updated model of chronic ankle instability (CAI). The outcome is determined at least 12 months after the initial ankle sprain. Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; HRQOL, health-related quality of life.

Source: Hertel, J., & Corbett, R. O. (2019). An Updated Model of Chronic Ankle Instability. *Journal of athletic training*, 54(6), 572–588.



Fig 1. Pictures of the realization of the “Figure of eight” test, which is used to measure the ankle swelling and takes part in the ROAST assessment.



Fig 2. Picture of the final position of the weight bearing lunge test, which is used to evaluate the ankle dorsiflexion range of motion and takes part in the ROAST assessment.



Fig 3. Picture of the final position of the posterior talar glide test which is used to measure the posterior glide of the talus in the ankle mortise and takes part in the ROAST assessment.



Fig 4. Pictures of the ‘opened eyes’ holding positions of the Balance Error Scoring System (BESS) which evaluates the static postural balance and takes part in the ROAST assessment.



Fig 5. Pictures of the final position (for this patient) of the modified YBT which is used to evaluate the dynamic postural balance and takes part in the ROAST assessment.

TEGNER ACTIVITY LEVEL SCALE

Please indicate in the spaces below the **HIGHEST** level of activity that you participated in **BEFORE YOUR INJURY** and the highest level you are able to participate in **CURRENTLY**.

BEFORE INJURY: Level _____ CURRENT: Level _____

Level 10	Competitive sports- soccer, football, rugby (national elite)
Level 9	Competitive sports- soccer, football, rugby (lower divisions), ice hockey, wrestling, gymnastics, basketball
Level 8	Competitive sports- racquetball or bandy, squash or badminton, track and field athletics (jumping, etc.), down-hill skiing
Level 7	Competitive sports- tennis, running, motorcars speedway, handball
	Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball, squash, racquetball, running
Level 6	Recreational sports- tennis and badminton, handball, racquetball, down-hill skiing, jogging at least 5 times per week
Level 5	Work- heavy labor (construction, etc.)
	Competitive sports- cycling, cross-country skiing,
	Recreational sports- jogging on uneven ground at least twice weekly
Level 4	Work- moderately heavy labor (e.g. truck driving, etc.)
Level 3	Work- light labor (nursing, etc.)
Level 2	Work- light labor
	Walking on uneven ground possible, but impossible to back pack or hike
Level 1	Work- sedentary (secretarial, etc.)
Level 0	Sick leave or disability pension because of knee problems

Y Tegner and J Lysohm. Rating Systems in the Evaluation of Knee Ligament Injuries. *Clinical Orthopedics and Related Research*. Vol. 198: 43-49, 1985.

Fig 6. Tegner activity level scale which takes part in the ROAST assessment.

Source : Delahunt, E., Bleakley, C. M., Bossard, D. S., Caulfield, B. M., Docherty, C. L., Doherty, C., Fourchet, F., Fong, D. T., Hertel, J., Hiller, C. E., Kaminski, T. W., McKeon, P. O., Refshauge, K. M., Remus, A., Verhagen, E., Vicenzino, B. T., Wikstrom, E. A., & Gribble, P. A. (2018). Clinical assessment of acute lateral ankle sprain injuries (ROAST): 2019 consensus statement and recommendations of the International Ankle Consortium. *British journal of sports medicine*, 52(20), 1304–1310.

French version of the Foot Ankle Ability Measurement (F-FAAM)
Évaluation des capacités fonctionnelles du pied et de la cheville (FAVQ)

En raison de votre pied et de votre cheville, quel est le niveau de difficulté pour :

	Pas de difficulté	Difficulté légère	Difficulté modérée	Difficulté sévère	Incapable de le faire	N/A
	4	3	2	1	0	/
Marcher 5 minutes ou moins	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Marcher environ 10 minutes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Marcher 15 minutes ou plus	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Les tâches ménagères	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Les activités de la vie quotidienne	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Les soins personnels	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Un travail léger à modéré (se tenir debout, marcher)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Un travail lourd (pousser/ tirer, grimper, porter)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Les activités de loisirs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A combien estimez-vous votre niveau actuel de fonctionnement dans les activités habituelles de votre vie quotidienne de 0 à 100, 100 étant votre niveau de fonctionnement avant votre problème de pied ou de cheville, 0 étant l'incapacité à faire le moindre de vos activités quotidiennes habituelles ?

/64
 (Score calculé : %)

Évaluation des capacités fonctionnelles du pied et de la cheville (SPORT)

En raison de votre pied et de votre cheville, quel est le niveau de difficulté pour :

Si l'activité en question est limitée par autre chose que votre pied ou votre cheville, notes non applicable (N/A).

	Pas de difficulté	Difficulté légère	Difficulté modérée	Difficulté sévère	Incapable de le faire	N/A
	4	3	2	1	0	/
Courir	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sauter	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Se réceptionner d'un saut	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Démarrer et s'arrêter rapidement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Faire des pas chausés / des déplacements latéraux	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Activités sportives à faible impact (peu de chocs)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Capacité à endosser votre activité sportive avec votre technique habituelle	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Capacité à endosser votre sport aussi longtemps que vous le souhaitez	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A combien estimez-vous votre niveau actuel de fonctionnement dans les activités habituelles de votre vie quotidienne de 0 à 100, 100 étant votre niveau de fonctionnement avant votre problème de pied ou de cheville, 0 étant l'incapacité à faire le moindre de vos activités quotidiennes habituelles ?

/32
 (Score calculé : %)

ICC - AVQ -08N / SPORT -08N (Gribble et al. 2013)

A

B

Fig 7. Foot and Ankle Ability Measure (FAAM) questionnaire. A: ADL subscale, B: Sports subscale. Both subscales of the FAAM take part in the ROAST assessment.

Source : Martin, R. L., Irrgang, J. J., Burdett, R. G., Conti, S. F., & Van Swearingen, J. M. (2005). Evidence of validity for the Foot and Ankle Ability Measure (FAAM). *Foot & ankle international*, 26(11), 968–983.

Appendix 2: French version of the Cumberland Ankle Instability Tool

Pour CHAQUE question, merci de cocher LA phrase qui décrit le MIEUX vos chevilles.


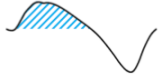






	Gauche	Droite	Score
1. J'ai des douleurs à la cheville			
Jamais	<input type="checkbox"/>	<input type="checkbox"/>	5
Quand je fais du sport	<input type="checkbox"/>	<input type="checkbox"/>	4
Quand je cours sur des surfaces irrégulières	<input type="checkbox"/>	<input type="checkbox"/>	3
Quand je cours sur des surfaces planes	<input type="checkbox"/>	<input type="checkbox"/>	2
Quand je marche sur des surfaces irrégulières	<input type="checkbox"/>	<input type="checkbox"/>	1
Quand je marche sur des surface planes	<input type="checkbox"/>	<input type="checkbox"/>	0
2. Ma cheville me semble INSTABLE quand			
Jamais	<input type="checkbox"/>	<input type="checkbox"/>	4
Parfois quand je fais du sport (pas à chaque fois)	<input type="checkbox"/>	<input type="checkbox"/>	3
A chaque fois que je fais du sport	<input type="checkbox"/>	<input type="checkbox"/>	2
Parfois lors d'activités quotidiennes	<input type="checkbox"/>	<input type="checkbox"/>	1
Fréquemment lors d'activités quotidiennes	<input type="checkbox"/>	<input type="checkbox"/>	0
3. Quand je pivote BRUSQUEMENT, j'ai l'impression que ma cheville est INSTABLE			
Jamais	<input type="checkbox"/>	<input type="checkbox"/>	3
Parfois quand je cours	<input type="checkbox"/>	<input type="checkbox"/>	2
Souvent quand je cours	<input type="checkbox"/>	<input type="checkbox"/>	1
Quand je marche	<input type="checkbox"/>	<input type="checkbox"/>	0
4. Quand je descends les escaliers, j'ai l'impression que ma cheville est INSTABLE			
Jamais	<input type="checkbox"/>	<input type="checkbox"/>	3
Si je vais vite	<input type="checkbox"/>	<input type="checkbox"/>	2
Occasionnellement	<input type="checkbox"/>	<input type="checkbox"/>	1
Toujours	<input type="checkbox"/>	<input type="checkbox"/>	0
5. Quand je me tiens sur UNE jambe, j'ai l'impression que ma cheville est INSTABLE			
Jamais	<input type="checkbox"/>	<input type="checkbox"/>	2
Quand je suis sur la pointe du pied	<input type="checkbox"/>	<input type="checkbox"/>	1
Quand j'ai le pied à plat	<input type="checkbox"/>	<input type="checkbox"/>	0
6. J'ai l'impression que ma cheville est INSTABLE quand			
Jamais	<input type="checkbox"/>	<input type="checkbox"/>	3
Je sautille d'un côté à l'autre	<input type="checkbox"/>	<input type="checkbox"/>	2
Je sautille sur place	<input type="checkbox"/>	<input type="checkbox"/>	1
Je saute	<input type="checkbox"/>	<input type="checkbox"/>	0
7. J'ai l'impression que ma cheville est INSTABLE quand			
Jamais	<input type="checkbox"/>	<input type="checkbox"/>	4
Je cours sur des surfaces irrégulières	<input type="checkbox"/>	<input type="checkbox"/>	3
Je trotte sur des surfaces irrégulières	<input type="checkbox"/>	<input type="checkbox"/>	2
Je marche sur des surfaces irrégulières	<input type="checkbox"/>	<input type="checkbox"/>	1
Je marche sur des surfaces planes	<input type="checkbox"/>	<input type="checkbox"/>	0
8. HABITUELLEMENT, quand ma cheville commence à se tordre, je peux l'arrêter			
Immédiatement	<input type="checkbox"/>	<input type="checkbox"/>	3
Souvent	<input type="checkbox"/>	<input type="checkbox"/>	2
Parfois	<input type="checkbox"/>	<input type="checkbox"/>	1
Jamais	<input type="checkbox"/>	<input type="checkbox"/>	0
Je ne me suis jamais tordu la cheville	<input type="checkbox"/>	<input type="checkbox"/>	3
9. Après un incident HABITUEL de torsion de cheville, ma cheville revient à la « normale »			
Presque immédiatement	<input type="checkbox"/>	<input type="checkbox"/>	3
En moins d'une journée	<input type="checkbox"/>	<input type="checkbox"/>	2
En un à deux jours	<input type="checkbox"/>	<input type="checkbox"/>	1
En plus de deux jours	<input type="checkbox"/>	<input type="checkbox"/>	0
Je ne me suis jamais tordu la cheville	<input type="checkbox"/>	<input type="checkbox"/>	3

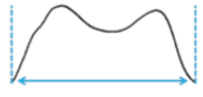
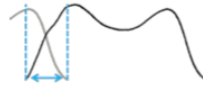




Fig 8. Cumberland Ankle Instability Tool (CAIT) which takes part in the ROAT assessment.



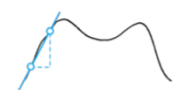

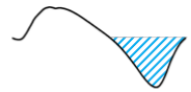
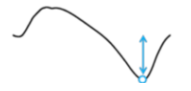


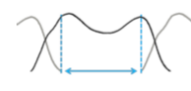
Source : Vuurberg G, Kluit L, van Dijk CN. The Cumberland Ankle Instability Tool (CAIT) in the Dutch population with and without complaints of ankle instability. *Knee Surg Sports Traumatol Arthrosc.* 2018 Mar;26(3):882-891.

TABLE 2. Operational definitions for the walking biomechanical variables

Source : <https://www.hpcosmos.com/en/products/running-machines/pluto-lt>

Dependent variable	Definition	Illustration
Base of Support Width (cm)	The average lateral distance between both feet during the contact phases	
Braking Impulse (%BW. s)	The integral, or area under the fore-aft force time curve during the braking phase of the step.	
Braking Peak Force (%BW)	The fore-aft braking peak force decelerating the body.	
Cadence (spm)	The number of foot strikes per minute.	
COM Fore-Aft Displ. (mm)	The fore-aft displacement (maximum position – minimum position) of the body center of mass during a step, obtained by double integration of the fore-aft force signal.	
COM Lateral Displ. (mm)	The lateral displacement (maximum position – minimum position) of the body center of mass during a step, obtained by double integration of the lateral force signal.	
COM Path (mm)	The length of the 3D path traveled by the body center of mass during a step.	
COM Vertical Displ. (mm)	The vertical displacement (maximum position – minimum position) of the body center of	

	mass during a step, obtained by double integration of the vertical force signal.	
Contact Duration (%stride)	The time duration from the initial heel contact to the final toe-off or the duration for which force is applied during a foot strike.	
Double Support Duration (%stride)	The period during a foot strike in which the body is supported by both feet. (The time from the heel strike of the one foot up to the toe-off of the other foot).	
Duty Factor	The ratio of Contact duration / Stride duration.	$\frac{t_c}{t_{stride}}$
L/P Peak Ratio	The ratio of loading vertical peak (L) / push-off vertical peak (P).	
Lateral Push Impulse (%BW. s)	The integral, or area under the lateral force time curve during the second phase of the step (positive area for the left steps, negative for the right steps).	
Lateral Push Peak Force (%BW)	The lateral peak force pushing the body laterally away from the side of the supporting foot. This peak force is taken as the maximal force occurring after the Lateral Strike Peak.	
Lateral Strike Impulse (%BW. s)	The integral, or area under the lateral force time curve during the first phase of the step (negative area for the left steps, positive for the right steps).	

<p>Lateral Strike Peak Force (%BW)</p>	<p>The lateral peak force under the front foot, during the first phase of the step, pushing the body laterally towards the side of the front foot.</p>	
<p>Loading Peak Force (%BW)</p>	<p>The first vertical peak force.</p>	
<p>Loading Rate (%BW/ms)</p>	<p>The slope of the vertical force time curve during the loading phase, taken from one point at 20% of first peak force and one point at 80% of first peak force.</p>	
<p>Mid-Support Force (%BW)</p>	<p>The minimum vertical force between first and second peak.</p>	
<p>Propulsive Impulse (%BW.s)</p>	<p>The integral, or area under the fore-aft force time curve during the propulsion phase of the step.</p>	
<p>Propulsive Peak Force (%BW)</p>	<p>The fore-aft propulsive peak force accelerating the body.</p>	
<p>Push-Off Peak Force (%BW)</p>	<p>The second vertical peak force</p>	
<p>Push-Off Rate (%BW/s)</p>	<p>The slope of the vertical force time curve during the unloading phase, taken from one point at 80% of second peak force and one point at 20% of second peak force.</p>	
<p>Single Support Duration (%stride)</p>	<p>The period during a foot strike in which the body is supported by only one foot.</p>	

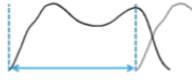

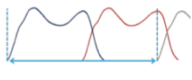

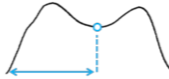

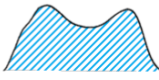


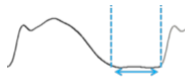








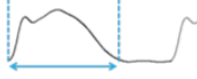







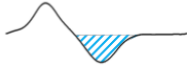




<p>Step Duration (%stride)</p>	<p>The time duration from the initial heel contact of one foot to the next initial heel contact of the opposite foot.</p>	
<p>Step Length (cm)</p>	<p>The fore-aft distance from a foot's initial contact to the initial contact of the opposite foot</p>	
<p>Stride Duration (ms)</p>	<p>The time duration from the initial contact of the left foot to the next initial contact of the left foot.</p>	
<p>Time to B-P Transition (%stride)</p>	<p>The time from the initial foot contact to the time when the fore-aft force is null, corresponding to the transition between braking and propulsive phases.</p>	
<p>Time to Mid-Support (%stride)</p>	<p>The time from the initial foot contact to the time when the mid-support force occurs.</p>	
<p>Time to Push-Off Peak (%stride)</p>	<p>The time from the initial foot contact to the time when the second vertical peak force occurs.</p>	
<p>Vertical Impulse (%BW. s)</p>	<p>The integral, or area under the vertical force time curve during the foot strike.</p>	
<p>Walk Ratio (cm/spm)</p>	<p>The ratio of Step length / Cadence, indicating the overall neuromotor gait control (higher value indicates a higher control).</p>	

TABLE 3. Operational definitions for the running biomechanical variables

Source : <https://www.hpcosmos.com/en/products/running-machines/pluto-lt>

Dependent variable	Definition	Illustration
Active Peak Force (%BW)	The vertical peak force during the foot contact, after the impact peak.	
Aerial Duration (% stride)	The time during which no force is applied during a step.	
Base of Support Width (cm)	The average lateral distance between both feet during the contact phases	
Braking Impulse (%BW. s)	The integral, or area under the fore-aft force time curve during the braking phase of the step.	
Braking Peak Force (%BW)	The fore-aft braking peak force decelerating the body.	
Cadence (spm)	The number of foot strikes per minute.	
COM Fore-Aft Displ. (mm)	The fore-aft displacement (maximum position – minimum position) of the body center of mass during a step, obtained by double integration of the fore-aft force signal.	
COM Lateral Displ. (mm)	The lateral displacement (maximum position – minimum position) of the body center of mass during a step, obtained by	

	double integration of the lateral force signal.	
COM Path (mm)	The length of the 3D path traveled by the body center of mass during a step.	 A 3D coordinate system with x, y, and z axes. A blue arrow indicates the path of the body center of mass, which forms a loop in the horizontal plane and moves forward along the z-axis.
COM Vertical Displ. (mm)	The vertical displacement (maximum position –minimum position) of the body center of mass during a step, obtained by double integration of the vertical force signal.	 A 3D coordinate system with x, y, and z axes. A blue double-headed vertical arrow indicates the vertical displacement of the body center of mass along the z-axis.
Contact Duration (%stride)	The time duration from the initial foot contact to the final toe-off or the duration for which force is applied during a step.	 A line graph showing a force signal over time. A blue double-headed arrow indicates the duration of contact, from the start of the force signal to the end.
Duty Factor	The ratio of Contact duration / Stride duration.	 A small box containing the equation $\frac{t_c}{t_{stride}}$.
Lateral Push Impulse (%BW. s)	The integral, or area under the lateral force time curve during the second phase of the step (positive area for the left steps, negative for the right steps).	 A line graph showing a lateral force signal over time. The area under the curve during the second phase is shaded with blue diagonal lines.
Lateral Push Peak Force (%BW)	The lateral peak force pushing the body laterally away from the side of the supporting foot. This peak force is taken as the maximal force occurring after the Lateral Strike Peak.	 A line graph showing a lateral force signal over time. A blue arrow points to the peak of the force signal during the second phase.
Lateral Strike Impulse (%BW. s)	The integral, or area under the lateral force time curve during the first phase of the step (negative area for the left steps, positive for the right steps).	 A line graph showing a lateral force signal over time. The area under the curve during the first phase is shaded with blue diagonal lines.

<p>Lateral Strike Peak Force (%BW)</p>	<p>The lateral peak force under the front foot, during the first phase of the step, pushing the body laterally towards the side of the front foot.</p>	
<p>Leg Stiffness (%BW/m)</p>	<p>The stiffness of the leg spring (K_{leg}) computed as the ratio of the maximal vertical force to the compression of the leg.</p>	
<p>Loading Rate (%BW/ms)</p>	<p>The slope of the vertical force time curve during the loading phase, taken from one point at 20% of first peak force and one point at 80% of first peak force.</p>	
<p>Propulsive Impulse (%BW. s)</p>	<p>The integral, or area under the fore-aft force time curve during the propulsion phase of the step.</p>	
<p>Propulsive Peak Force (%BW)</p>	<p>The fore-aft propulsive peak force accelerating the body</p>	
<p>Push Off Rate (%BW/s)</p>	<p>The slope of the vertical force time curve during the unloading phase, taken from one point at 80% of active peak force and one point at 20% of active peak force.</p>	
<p>Step Length (cm)</p>	<p>The fore-aft distance from a foot's initial contact to the initial contact of the opposite foot</p>	
<p>Stride Duration (ms)</p>	<p>The time duration from the initial contact of the left foot to the next initial contact of the left foot.</p>	

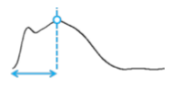




Time to Active Peak (%stride)	The time from the initial foot contact to the time when the active peak force occurs.	
Time to B-P Transition (%stride)	The time from the initial foot contact to the time when the fore-aft force is null, corresponding to the transition between braking and propulsive phases.	
Time to Braking Peak (%stride)	The time from the initial foot contact to the time when the braking peak force occurs.	
Time to Impact Peak (%stride)	The time from the initial foot contact to the time when the impact peak force occurs.	
Time to Propulsive Peak (%stride)	The time from the initial foot contact to the time when the propulsive peak force occurs.	

TABLE 11: STROBE Guidelines completion

	Page number	Recommendation
Title and abstract	/	Indicate the study's design with a commonly used term in the title or the abstract
	/	Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	1-2	Explain the scientific background and rationale for the investigation being reported
Objectives	2	State specific objectives, including any prespecified hypotheses
Methods		
Study design	3	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	4	Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls
Data sources/ measurement	5-7	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	6	Describe any efforts to address potential sources of bias
Study size	5	Explain how the study size was arrived at
Statistical methods	7	Describe all statistical methods, including those used to control for confounding
	8	Describe any methods used to examine subgroups and interactions
Results		
Participants	8	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
	8	Give reasons for non-participation at each stage
Descriptive data	8 - 9	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
Outcome data	8	Report numbers in each exposure category, or summary measures of exposure
Main results	10-16	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
Other analyses	17-26	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	27	Summarise key results with reference to study objectives
Limitations	32-33	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	27-32	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalizability	33-34	Discuss the generalisability (external validity) of the study results

Background: There are quite a few studies that compare 2 or 3 groups of subjects related to ankle sprain. But there are no studies comparing the four groups: healthy subjects (HEA), subjects with ankle sprains (LAS), subjects with ankle sprains but who are recovered (COPERS) and subjects with chronic ankle instability (CAI). Therefore, this study aimed to fill the gaps in the literature and would allow us to emphasize the biomechanical alterations existing in these participants, compare them, and then direct therapists towards an effective therapy, potentially lowering the likelihood of sprain recurrence in runners.

Objectives: To report gait analysis, i.e., walking and running, between runners with different clinical history of ankle sprain, i.e., healthy, copers, chronic ankle instability and recent ankle sprain.

Study design: Cross-sectional cohort study.

Method: Participants completed three questionnaires from June to September 2023. Eligible participants were enrolled and assigned to their corresponding category, based on these eligibility criteria i.e., HEA, COPERS, LAS or CAI. To be included, all participants had to be active runners. Each runner underwent a complete clinical examination of the ankles as well as an analysis of the running biomechanics.

Results: Significantly reduced mechanical work recovery and reduced step duration were reported for the participant with recent history of ankle sprain during the walking. There were no significant differences of running biomechanics between groups.

Conclusion: Ankle sprain could alter walking gait compared to healthy individual without affecting running.

Key words: running, ankle sprain, biomechanics, treadmill