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ORIGINAL ARTICLE

## Lower limb alignment characteristics are not associated with running injuries in runners: Prospective cohort study

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### Abstract

There is conflicting evidence on the association between lower limb alignment characteristics and the incidence of running-related injury (RRI). Therefore, the primary aim of this study was to investigate the association between lower limb alignment characteristics and the incidence proportion of RRI in a convenience sample of recreational runners. A total of 89 recreational runners were included in this prospective cohort study. These participants had been running for at least six months and were injury-free at baseline. Lower limb alignment measurements were conducted in order to calculate lower limb discrepancy, Q-angle, subtalar angle and plantar index. All participants also answered a baseline and biweekly online surveys about their running routine, history of RRI and newly developed RRI over a period of 12 weeks. The prevalence of previous RRI and the 12-week incidence proportion of new RRI were calculated. Logistic regression analysis was performed to estimate the association between lower limb length discrepancy, Q-angle, subtalar angle and plantar arch index with the incidence proportion of RRI. The prevalence of previous RRI was 55.1% ( $n = 49$ ). The 12-week incidence proportion of new RRI was 27.0% ( $n = 24$ ). Muscle injuries and tendinopathies were the main types of RRI identified. The lower leg and the knee were the main anatomical regions affected. We did not find significant associations between lower limb length discrepancy, Q-angle, subtalar angle and plantar arch index and injury occurrence.

**Keywords:** *Injury & prevention; musculoskeletal; measurement*

### Introduction

Running is one of the most popular types of physical activity worldwide (van Middelkoop, Kolkman, van Ochten, Bierma-Zeinstra, & Koes, 2007). Current literature suggests that running promotes many health benefits such as reducing risk factors for cardiovascular diseases and increasing cardiorespiratory capacity (Hespanhol Junior, van Mechelen, Postuma, & Verhagen, 2015). Running also has positive effects on mental health and weight control (Jakobsen, Kroner, Schmidt, & Kjeldsen, 1994; Marti, 1991; Williams, 1997, 2007, 2008). Therefore, many people seeking for a healthier lifestyle eventually choose running as their preferred type of

exercise. However, the risk of injury while running is quite high. Prevalence of running-related injury (RRI) ranges from 1.4% to 94.4% (Chandy & Grana, 1985; Lopes et al., 2011; Lopes, Hespanhol Junior, Yeung, & Costa, 2012; Reinking, 2006) depending on the injury definition, study design and type of runners investigated (van Gent et al., 2007; Yamato, Saragiotto, & Lopes, 2015; Yamato, Saragiotto, Hespanhol Junior, Yeung, & Lopes, 2015).

Despite previous injuries being considered as the main risk factor of RRI (Hespanhol Junior, Costa, & Lopes, 2013), a recent systematic review also found that a high Q-angle was associated with RRI in two out of three prospective studies that analysed

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this variable (Saragiotto et al., 2014). In addition, it has been hypothesized that lower limb alignment characteristics, such as lower limb length discrepancy, right–left Q-angle difference, height of the medial longitudinal arch and subtalar angle may be associated with running injuries (Knapik et al., 2009; Knapik, Brosch, et al., 2010; Knapik, Trone, et al., 2010; Lun, Meeuwisse, Stergiou, & Stefanyshyn, 2004; Raissi, Cherati, Mansoori, & Razi, 2009; Rauh, Koepsell, Rivara, Margherita, & Rice, 2006; Rauh, Koepsell, Rivara, Rice, & Margherita, 2007; Wen, Puffer, & Schmalzried, 1998). The examination of the lower limb alignment characteristics assessed by common measurements is often used by physiotherapists, trainers and physicians in clinical practice. However, conflicting evidence is observed about the relationship between lower limb alignment characteristics and RRI (Lun et al., 2004; Rauh et al., 2007; van Gent et al., 2007; Wen et al., 1998). A better understanding of the relationship between intrinsic risk factors and RRI is important, it may help to identify runners at risk of RRI as well as assist in the development of RRI prevention programmes.

Therefore, the objectives of this study were: (1) to investigate the association between lower limb alignment characteristics and the incidence proportion of RRI in a convenience sample of recreational runners; (2) to assess the prevalence of the history of RRI and the incidence proportion of newly sustained RRI over a period of 12 weeks and (3) to describe the most common injuries and anatomic regions of these RRIs.

## Methods

### *Study design and participants*

This was a 12-week prospective cohort study with follow-ups performed biweekly. A convenience sample of 89 recreational runners (defined as those who run for fun regardless of distance, performance or race participation) registered as members of a Brazilian running events promoter who participated in a previous cohort (Hespanhol Junior et al., 2013). Participants met the following inclusion criteria: (1) aged  $\geq 18$  years, (2) running on a regular basis for at least six months, (3) free of any health condition that could preclude running, (4) free of musculoskeletal injury (muscles, tendons, joints, ligaments and/or bones) of the lower limbs and trunk. This study was approved by the Ethics Committee of the *Universidade Cidade de São Paulo* (protocol number 13506583/2010).

The invitation email contained a detailed explanation about the study. After consenting to

participate (using an online consent form) the participants were invited to respond to an online baseline survey. The baseline survey contained information about running experience (in years), training frequency (times/week), mileage (km/week), duration (min/week), velocity (min/km), use of PCECH (pronation control, elevated cushioned heel) shoes and special insoles (other than the standard shoe insole). After completing the baseline survey, lower limb alignment measurements were measured as described below. These measurements were performed by two authors of this study (LCHJ and ACAC) at the university, in parks or at running event facilities, depending on the participants' choice or convenience.

Data collection consisted of six follow-up surveys sent to the runners by email every 14 days throughout the 12-week study period. Messages were sent by email every two weeks to remind the participants to complete the online survey for the previous two-week period. Reminders were sent after three days when the survey had not been returned. All of these emails contained a link directing the runners to the online follow-up survey. If the runner had not completed the survey eight days after the initial email, they were then contacted by phone to remind them to complete the survey either online or over the phone. There were only eight cases in which it was necessary to contact the participants by telephone or letter to collect the data because they did not react after the second reminder alert. Participants also reported if they missed any training due to musculoskeletal pain in the last two weeks, number of training sessions missed, pain intensity (measured on a 10-point numerical pain rating scale) and the description (type and anatomical location) of the new RRI. The runners were considered injured if they missed at least one training session due to musculoskeletal pain in the last two weeks (Hespanhol Junior et al., 2013; Hespanhol Junior, Costa, Carvalho, & Lopes, 2012). Table I describes the variables measured at baseline and at all follow-up. Complete online descriptions of the baseline and follow-up surveys were published elsewhere (Hespanhol Junior et al., 2012, 2013).

### *Lower limb alignment measurements*

*Lower limb length discrepancy.* The evaluation of lower limb length discrepancy (right–left lower limb length difference) was carried out with the participants in a supine position and with their lower limbs relaxed. The following anatomical references were identified: the anterior superior iliac spine (ASIS) and the centre of the medial malleolus of each lower limb. A

Table I. Baseline and follow-up variables collected during the study

Baseline	
Personal data	Age, gender, weight (kg) and height (cm).
Running history	Running experience (yr), training frequency (times/week), mileage (km/week), duration (min/week), velocity (min/km), use of PCECH shoes and special insoles (other than the standard shoe insole).
History of RRI	“Have you ever had some musculoskeletal injury related to running, located in your lower limbs or trunk, that was severe enough to cause a restriction of running for at least one training session?” (yes or no), number and description (type and anatomical region <sup>a</sup> ) of the previous RRI.
12-week follow-up (biweekly)	
Running exposure	Training frequency (times/week), mileage (km/week) and duration (min/training session).
New RRI	“Did you miss any training due to musculoskeletal pain in the last two weeks?” (yes or no), number, pain intensity (10-point numerical pain rating scale) and description (type and anatomical location <sup>a</sup> ) of the new RRI.

Abbreviations: RRI, running-related injury. PCECH, pronation control and/or elevated cushioned heel.

<sup>a</sup>The type and anatomical region options were based upon a list of symptoms and diagnosis used on a previous study.

measuring tape was used to determine the real length of the lower limbs, that is, the length between the ASIS of the hemipelvis to the centre of the ipsilateral medial malleolus of both lower limbs. The lower limb length discrepancy was considered normal when lower than 1.0 cm (Rauh et al., 2006; Santili, Waisberg, Akkari, Fávoro, & Prado, 1998).

*Q-angle.* The Q-angle was used for measuring the quadriceps femoris angle. The participant was wearing sports clothes and stood barefoot in an orthostatic position. The following anatomical references were identified: the ASIS, the centre of both patellae and both tibial tuberosities (Rauh et al., 2007). The same examiner carried out all measurements. A straight line was traced using a ruler from the ASIS to the centre of the patella, and a second line was traced from the centre of the patella to the tibial tuberosity. The angle formed by the intersection of these two lines constitutes the Q-angle, which was measured by a universal goniometer. Values between 10° and 15° were considered normal for both genders (Rauh et al., 2007).

*Subtalar angle.* In order to measure subtalar angle, the participants stood on a 30-cm high platform and were instructed to keep their feet parallel and bearing the weight symmetrically between their lower limbs. The posterior calcaneal tuberosity and a point on the calcaneal tendon corresponding to the height of the medial malleolus were identified with adhesive labels. A photograph of the posterior distal third of the lower limbs was taken using a digital camera. The camera was positioned on a tripod centred on the participant and levelled at the same height as the platform. AutoCAD<sup>®</sup> 2005 (Autodesk, Inc., USA) was used to measure the subtalar angle. The evaluator drew one line between the two points marked with the adhesive labels and another line

perpendicular (90°) to the ground. The intersection of the lines resulted in an angle (McPoil & Cornwall, 1996) that was measured and classified as follows: normal subtalar angle (between 0° and 5°), varus subtalar angle (<0°) and valgus subtalar angle (>5°) (Eng & Pierrynowski, 1994).

*Plantar arch index.* The participants stood barefoot on a podoscope with 7.5 cm between their feet. A photograph of the footprint was taken with a digital camera positioned on a tripod in front of the podoscope. AutoCAD 2005<sup>®</sup> was used to analyse the images by drawing three lines: (1) one from a point at the 2nd metatarsophalangeal joint to a point at the posterior face of the calcaneus, which was named as the foot axle line; (2) the second line was based on the most prominent points of the 1st and 5th metatarsus and was drawn perpendicularly to the first line and (3) the third line was based on the most prominent points of the anterior portion of the medial and lateral calcaneus. After these lines were drawn, the foot could be divided into three areas: forefoot, midfoot and rearfoot. The three areas were measured in AutoCAD<sup>®</sup> 2005. The midfoot was divided by the sum of the three areas resulting in the arch index (Nakhaee, Rahimi, Abaee, Rezasoltani, & Kalantari, 2008). The measures were collected on each foot of the participants. The medial longitudinal arch was classified according to the following parameters: high longitudinal arch (index ≤ 0.21), normal longitudinal arch (index between 0.21 and 0.26) and low longitudinal arch (index ≥ 0.26) (Cavanagh & Rodgers, 1987).

#### Data analysis

Descriptive analysis of personal characteristics, running training, lower limb alignment and RRI characteristics was conducted. Normal distribution

was verified by visual inspection of histograms. Two-tailed *t*-tests were conducted to compare personal and running parametric continuous data between the recreational runners with and without a history of previous RRI. Mann–Whitney tests were used for non-parametric data. Chi-square tests were conducted to assess the association of the categorical data (gender, BMI, pace, training guidance, PCECH shoes, special insole and previous injury) at baseline.

Logistic regression analysis was performed to estimate the independent relationship between the lower limb alignment characteristics and the incidence proportion of RRI. The results of the logistic regression were expressed as odds ratios (ORs) with their respective 95% confidence intervals (95% CIs). All statistical analyses were performed in the SPSS version 20.

## Results

**Table II** provides baseline data of the 89 recreational runners included in the study. The mean age of the runners was 44.2 years (standard deviation [SD] = 10.6), and the median of years of running experience was 5.0 (interquartile range [IQR] = 6.0). Most of the participants were male (76.4%,  $n = 68$ ) and the mean BMI was 24.2 (SD = 3.5) kg/m<sup>2</sup>. During the 12-week follow-up period, the runners performed a mean frequency of 3.2 (SD = 1.2) training sessions/week, a median running mileage of 29.0 (IQR = 22.2) km/week and a mean duration of 70.2 (SD = 23.5) min/training session.

The prevalence of previous RRI was 55.1% ( $n = 49$ ). Forty-nine recreational runners reported a total of 78 previous RRIs. Of the previously injured runners, 49.0% ( $n = 24/49$ ) reported one RRI, 42.9% ( $n = 21/49$ ) reported two and 8.2% ( $n = 4/49$ ) reported three previous injuries. The 12-week incidence proportion of new RRI was 27.0% ( $n = 24$ ) or 7.7 RRIs per 1000 hours of running exposure. A total of 33 new RRIs was registered in 24 runners during the 12-week follow-up. The total running exposure of all 89 runners during the 12 weeks was 4281 hours. Of the newly injured runners, 70.8% ( $n = 17/24$ ) developed one, 25.0% ( $n = 6/24$ ) developed two and 4.2% ( $n = 1/24$ ) developed three RRIs. Of the newly injured runners who developed two or three RRIs during the follow-up, 28.6% ( $n = 2/7$ ) were recurrences. The data on the previous RRI and the 12-week new RRI are presented in **Table III**.

**Table IV** shows data on the lower limb alignment characteristics and the logistic regression analysis. Summary values for lower limb length discrepancy,

Q-angle and subtalar angle were classified as normal. However, half of the recreational runners had high plantar arch indices. No statistically significant associations between the lower limb alignment measurements and the incidence proportion of RRI were observed.

## Discussion

The prevalence of previous RRI was 55.1% ( $n = 49$ ) and the 12-week incidence proportion of new RRI was 27.0% ( $n = 24$ ) or 7.7 RRIs per 1000 hours of running exposure. Muscle injuries and tendinopathies were the main types of RRIs identified. The lower leg and the knee were the main anatomical regions affected. None of the lower limb alignment characteristics were statistically significantly associated with the incidence proportion of RRI.

The main RRIs were muscle injuries and tendinopathies. This was also found in a retrospective study (McKean, Manson, & Stanish, 2006). A systematic review about the prevalence and incidence proportion of RRI (Lopes et al., 2012) showed that tendinopathies are very frequent among runners. This systematic review also found that not only tendinopathies, but also medial tibial stress syndrome (shin splints) and plantar fasciitis are very common (Lopes et al., 2012). The lower incidence proportions of medial tibial stress syndrome and plantar fasciitis found in this study can be explained, because the majority of the studies included in the systematic review were conducted in marathon runners and/or during races. Our sample was composed by runners who may present a different injury profile due to lower mileage per week when compared to marathon runners. The lower leg and the knee were the most affected regions, as has also been observed in other studies (Buist et al., 2008; Taunton et al., 2002).

We found no association between lower limb alignment characteristics and the incidence proportion of RRI. These results are supported by previous studies leading to the conclusion that lower limb alignment characteristics are unlikely to be risk factors for RRI (Lun et al., 2004; van Gent et al., 2007; Wen et al., 1998).

Most people have no large in between-subject variation in lower limb alignment measurements, as can be seen in the results of this study. This may explain why we did not find associations between lower limb alignment characteristics and RRI. Nevertheless, the interpretation of our results should be cautious. Some lower limb alignment characteristics may be associated with a specific injury, but this study did not have sufficient power to conduct a sensitivity analysis regarding specific lower limb

Table II. Baseline characteristics of the recreational runners

Variables	All ( <i>n</i> = 89)	With history of injury ( <i>n</i> = 49)	Without history of injury ( <i>n</i> = 40)	<i>p</i>
Age <sup>a</sup>	44.2 (10.6)	45.4 (11.0)	42.8 (10.0)	.25
Gender <sup>b</sup>				
Male	76.4 (68)	77.6 (38)	75.0 (30)	
Female	23.6 (21)	22.4 (11)	25.0 (10)	.78
Height (cm) <sup>a</sup>	171.1 (9.7)	171.4 (10.1)	170.8 (9.2)	.79
Weight (kg) <sup>a</sup>	71.5 (15.3)	71.3 (13.6)	71.7 (17.2)	.92
BMI (kg/m <sup>2</sup> ) <sup>b</sup>				
Healthy	61.8 (55)	59.2 (29)	65.0 (26)	
Overweight	33.7 (30)	38.8 (19)	27.5 (11)	
Obese	4.5 (4)	2.0 (1)	7.5 (3)	.30
Running experience (years) <sup>c</sup>	5.0 (6.0)	5.0 (6.0)	4.0 (6.0)	.20
Frequency (times/week) <sup>a</sup>	3.8 (1.3)	3.8 (1.3)	3.9 (1.2)	.65
Mileage (km/week) <sup>c</sup>	35.0 (28.0)	35.0 (25.0)	40.0 (22.0)	.51
Duration (min/week) <sup>a</sup>	73.6 (25.2)	70.8 (22.8)	77.0 (27.8)	.25
Pace <sup>b</sup>				
3–4 min/km	4.5 (4)	2.0 (1)	7.5 (3)	
4–5 min/km	41.6 (37)	42.9 (21)	40.0 (16)	
5–6 min/km	36.0 (32)	36.7 (18)	35.0 (14)	
6–7 min/km	12.4 (11)	14.3 (7)	10.0 (4)	
7–8 min/km	5.6 (5)	4.1 (2)	7.5 (3)	.68
Training guidance <sup>b</sup>				
Running team	38.2 (34)	36.7 (18)	40.0 (16)	
Internet or friend	12.4 (11)	14.3 (7)	10.0 (4)	
None	49.4 (44)	49.0 (24)	50.0 (20)	.82
PCECH shoes <sup>b</sup>				
Yes	84.3 (75)	85.7 (42)	82.5 (33)	
No	15.7 (14)	14.3 (7)	17.5 (7)	.68
Special insole <sup>bd</sup>				
Yes	14.6 (13)	18.4 (9)	10.0 (4)	
No	85.4 (76)	81.6 (40)	90.0 (36)	.27
Previous injury <sup>b</sup>				
Yes	55.1 (49)	–	–	
No	44.9 (40)	–	–	–

Abbreviation: PCECH, pronation control and/or elevated cushioned heel.

<sup>a</sup>Continuous variables with parametric distribution are expressed by mean and standard deviation and were compared between recreational runners “with history of injury” and “without history of injury” by *t*-test.

<sup>b</sup>Gender and body mass index (BMI) are categorical variables and they are expressed by percentage and their respective number of recreational runners. The association between the recreational runners distribution “with history of injury” and “without history of injury” was checked by Chi-square test.

<sup>c</sup>Continuous variables with non-parametric distribution are expressed by median and interquartile range and were compared between recreational runners “with history of injury” and “without history of injury” Mann–Whitney test.

<sup>d</sup>Special insoles: other than the standard shoe insole.

alignment variables for each type of RRIs. Additionally, our results refer only to recreational runners. Other types of runners (e.g. marathoners, elite, novices) may have different RRI risk profiles (Tonoli, Cumps, Aerts, Verhagen, & Meeusen, 2010).

The strength of this study was the examination of the lower limb alignment characteristics assessed by common measurements related to everyday health-care professionals practice. The evaluation using common measurements can lead to an important clinical implication, because nowadays most physiotherapists, trainers and clinicians practice use static lower limb alignment measurements to explain RRI in their patients. As none of the lower

limb alignment characteristics was statistically significant associated with the incidence proportion of RRI during follow-up we suggest that new prevention strategies can be adopted focusing in modifiable variables in order to influence the development of RRI, for example, changing the training characteristics (Brill & Macera, 1995; Hespanhol Junior et al., 2012; Nielsen, Buist, Sorensen, Lind, & Rasmussen, 2012; Verhagen & Engbers, 2009; Verhagen, van Stralen, & van Mechelen, 2010).

This study had some limitations. The evaluations of the height of the medial longitudinal arch and subtalar angle were carried out statically. However, these evaluation methods for lower limb alignment chosen represent the clinical evaluation routinely used by

Table III. RRI by type and anatomical location

	Previous RRI % ( <i>n</i> )	12-week new RRI % ( <i>n</i> )	Duration of the new RRI in weeks <i>M</i> ( <i>SD</i> )	Lost training sessions/ week of the new RRI <i>M</i> ( <i>SD</i> )	Pain intensity of the new RRI <i>M</i> ( <i>SD</i> )
Overall RRI	100.0 (78)	100.0 (33)	2.9 (1.2)	2.7 (1.7)	4.9 (2.3)
<b>Type of RRI</b>					
Arthritis/Synovitis/Bursitis	3.8 (3)	3.0 (1)	2.0 <sup>a</sup>	2.0 <sup>a</sup>	9.0 <sup>a</sup>
Contusion/Haematoma/ Ecchymosis	1.3 (1)	3.0 (1)	4.0 <sup>a</sup>	5.5 (3.5)	4.5 (0.7)
Intense spasm or severe cramp	5.1 (4)	3.0 (1)	2.0 <sup>a</sup>	2.0 <sup>a</sup>	4.0 <sup>a</sup>
Low back pain	10.3 (8)	12.1 (4)	2.5 (1.0)	2.4 (1.1)	5.2 (2.4)
Luxation, subluxation	1.3 (1)	3.0 (1)	2.0 <sup>a</sup>	3.0 <sup>a</sup>	3.0 <sup>a</sup>
Medial tibial stress syndrome or stress fracture (overload)	6.4 (5)	3.0 (1)	4.0 <sup>a</sup>	1.5 (0.7)	7.0 (0.0)
Meniscal or cartilage damage	5.1 (4)	9.1 (3)	2.0 (0.0)	1.7 (1.2)	4.3 (2.9)
Muscle strain/Rupture/Tear	25.6 (20)	30.3 (10)	3.0 (1.4)	2.9 (2.1)	4.9 (2.4)
Plantar fasciitis	9.0 (7)	–	–	–	–
Sprain (injury of the joint and/or ligaments)	7.7 (6)	–	–	–	–
Tendinopathy	16.7 (13)	12.1 (4)	4.0 (1.6)	2.4 (1.3)	5.3 (1.9)
Not identified	7.7 (6)	21.2 (7)	2.6 (1.0)	2.7 (1.4)	4.1 (2.7)
<b>Anatomical region of RRI</b>					
Achilles tendon (Calcaneal)	5.1 (4)	3.0 (1)	4.0 <sup>a</sup>	1.0 (0.0)	4.5 (0.7)
Ankle	7.7 (6)	9.1 (3)	2.7 (1.2)	2.0 (1.4)	6.5 (3.3)
Cervical spine	2.6 (2)	3.0 (1)	4.0 <sup>a</sup>	6.0 (4.2)	3.0 (1.4)
Foot / Toes	11.5 (9)	12.1 (4)	3.0 (2.0)	2.5 (1.4)	5.3 (2.7)
Hip / Groin	3.8 (3)	–	–	–	–
Knee	23.1 (18)	21.2 (7)	2.9 (1.1)	2.6 (1.3)	3.7 (1.6)
Lower leg	23.1 (18)	24.2 (8)	3.3 (1.5)	3.2 (1.9)	5.2 (2.4)
Lumbar spine	11.5 (9)	15.2 (5)	2.4 (0.9)	2.3 (1.0)	5.8 (2.6)
Thigh	11.5 (9)	12.1 (4)	2.0 (0.0)	1.8 (1.0)	4.5 (1.3)

Abbreviations: RRI, running-related injury. % (*n*), percentage (number of RRI). *M* (*SD*), mean (standard deviation).

<sup>a</sup>Absolute numbers.

Table IV. Lower limb alignment measurements in injured and non-injured runners, and the logistic regression analysis related to the associations between these measurements and the incidence proportion of RRI

Variables	Injured	Non-injured	Logistic regression OR (95% CI)
Lower limb length discrepancy (cm), mean (SD)	0.5 (0.6)	0.4 (0.6)	1.3 (0.6 to 2.7)
Q-angle (°), mean (SD)	10.1 (5.1)	11.8 (5.0)	0.9 (0.8 to 1.0)
Subtalar angle (°), mean (SD)	3.7 (1.8)	3.9 (2.5)	1.0 (0.8 to 1.2)
Plantar arch index, % ( <i>n</i> )			
Normal (0.21 to 0.26)	25.0 (6)	24.6 (16)	1
High (≤ 0.21)	50.0 (12)	50.8 (33)	1.0 (0.3 to 3.1)
Low (≥ 0.26)	25.0 (6)	24.6 (16)	1.0 (0.3 to 3.8)

Abbreviations: RRI, running-related injury. SD, standard deviation. OR, odds ratio. CI, confidence interval.

All lower limb alignment measurements were entered in the multivariate model.

physiotherapists, trainers and physicians in clinical practice, since they are inexpensive and easy to perform. Moreover, regarding alignment measurements, the Q-angle was measured while instructing the runner to remain comfortable, without predetermining the plantar position, which may have influenced this variable. The RRIs were self-reported and the study logistics precluded the diagnosis confirmation by a medical doctor. Future studies should

evaluate the influence of lower limb alignment characteristics in specific types of RRIs and with a longer follow-up period.

### Conclusions

We did not find significant associations between lower limb length discrepancy, Q-angle, subtalar angle and plantar arch index and injury occurrence.

The 12-week incidence proportion of RRI was 27.0% or 7.7 RRIs per 1000 hours of running exposure, and the prevalence of previous RRI in recreational runners at the baseline was 55.1%. Muscle injuries and tendinopathies were the most commonly RRIs registered. The lower leg and the knee were the main anatomical regions affected.

### Disclosure statement

No potential conflict of interest was reported by the authors.

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