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ABSTRACT

The purpose of this study was to determine the foot strike patterns (FSP), rearfoot position at initial contact (RPic, i.e., No INV/EVE) and foot rotation in children in relation to age. A total of 932 children aged 3 to 16 years participated in this study. A sagittal and frontal-plane video was recorded using a high-speed camcorder to analyse these variables. There is a significant increase ($p < 0.001$) of rearfoot strike patterns (RFS) prevalence in relation to age; e.g. preschool children (3–6 years old) displayed an RFS prevalence 46.65% and the adolescent population(15–16 years old) an RFS prevalence 92.20%. The total RFS prevalence in all samples was 69.25%. There was a significant reduction ($p < 0.001$) of prevalence of RPic in relation to age groups; preschool children displayed a prevalence of RPic 60.37% and the adolescent population 10%. There was a significant reduction ($p < 0.001$) of prevalence of no foot rotation in relation to age groups; preschool children displayed a prevalence of no foot rotation 48.95% and the adolescent population 13.55%. In conclusion, FSP in children are influenced by age. It is noteworthy that the RFS prevalence of children is lower in comparison to the adult population.

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KEYWORDS
Running; children; age; foot strike patterns

1. Introduction

Motor skills such as running are essential in most children's physical activities and promote physical activity and fitness (Nguyen, Obeid, & Timmons, 2011). The majority (70–75%) of 4-year-old preschoolers show mastery in running (Hardy, King, Farrell, Macniven, & Howlett, 2010). Running patterns are influenced by numerous internal factors such as sex, age and physical fitness (Ferber, Davis, & Williams, 2003; Fukuchi, Stefanyshyn, Stirling, Duarte, & Ferber, 2014; Sinclair & Selfe, 2015); and external factors such as running surfaces and footwear (An, Rainbow, & Cheung, 2015; Gruber, Silvernail, Brueggemann, Rohr, & Hamill, 2013; Lieberman et al., 2010; Muñoz-Jimenez, Latorre-Román, Soto-Hermoso, & García-Pinillos, 2015). Many previous studies showed that running biomechanics – specifically foot strike patterns (FSP) -, in both adults and children, are influenced by shod-unshod conditions (Almeida, Davis, & Lopes, 2015; Latorre Román, Balboa, & Pinillos, 2017; Lieberman et al., 2010; Muñoz-Jimenez et al., 2015).

Recently, there has been an increased interest in FSP analysis in runners because a relationship between FSP and lower extremity injury has been suggested by previous studies (Boyer & Derrick, 2017; Molloy, 2016). Many children participate in organised sport activities, such as endurance races, resulting in an increase in lower limb injuries (Krabak, Snitily, & Milani, 2016). This might be related to the dynamics of the foot in contact with the ground. The pattern of the contact depends to some extent on the speed, running surface, footwear, and fatigue (Daoud et al., 2012). Although running with fore foot strike (FFS) seems to be a characteristic of human evolution (Daoud et al., 2012), adult amateur endurance runners exhibit a high prevalence – between 74.9% and 95.4% – of rearfoot strike (RFS) (Hasegawa et al., 2007; Kasmer, Liu, Roberts, & Valadao, 2013; Larson et al., 2011; Latorre-Román et al., 2015). RFS has been associated with higher vertical loading, higher collision forces and greater ankle stiffness (Almeida et al., 2015; Butler, Crowell, & Davis, 2003; Hamill, Gruber, & Derrick, 2014; Lieberman et al., 2010), and some previous work have suggested its association with a greater injury risk (Daoud et al., 2012). Moreover, other variables such as rearfoot eversion (Pohl, Hamill, & Davis, 2009) and misalignments in lower limbs (e.g., tibial external rotation relative to the femur) (Barton, Levinger, Menz, & Webster, 2009) have been associated to running-related injury risk.

Additionally, despite the numerous studies trying to define the advantages and disadvantages of certain FSP and footwear in the adult population, no studies have examined FSP in children in relation to age. Research into footwear use in children is also of great interest as footwear can have a lasting impact on the developing foot (Franklin, Grey, Heneghan, Bowen, & Li, 2015). More information about FSP during running in children may lead to more appropriate shoe designs for children or a better understanding of the role played by FSP for childhood foot development.

Based on the previous information and taking into account that children are not influenced by so many years of using cushioned shoes, the main purpose of the current study was

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to determine the FSP, rearfoot position at initial contact (RPic) (i.e., no inversion [INV]/eversion [INV]) and foot rotation in children while running at a comfortable self-selected velocity, and to examine the dynamic of those parameters over childhood. The authors hypothesize that the proportion of RFS would be lower in early ages and that the proportion of RPic and no foot rotation would be higher.

2. Methods

2.1. Participants

A total of 932 children aged 3 to 16 years participated in this study (age = 8.49 ± 4.01 years old, body mass index [BMI] = 18.59 ± 3.75 kg/m^2). The sample was divided into seven age groups: 3–4 years old (n = 187), 5–6 years old (n = 186), 7–8 years old (n = 123), 9–10 years old (n = 129), 11–12 years old (n = 107), 13–14 years old (n = 115) and 15–16 years old (n = 85). Demographic characteristics revealed that 526 children were male and 406 were female, and they were selected from 31 schools in southern Spain. The sample was selected by convenience in a large geographical area of Andalusia in both urban and rural areas. Inclusion criteria included being free from physical and/or intellectual disabilities. More information about the participants is shown in Table 1. Parents voluntarily signed an informed consent form for the participation of their children in this study. This study was completed in accordance with the norms of the Declaration of Helsinki (2013 version) and was approved by the Ethics Committee of the University of Jaen (Spain).

2.2. Materials and testing

Body mass (kg) was measured using a weighing scale (Seca 899, Hamburg, Germany), and body height (cm) was measured with a stadiometer (Seca 222, Hamburg, Germany). The BMI was calculated by dividing body mass (kg) by body height^2 (in metres). Sociodemographic data, such as physical activity per week (h/week), was obtained through the Krece Plus questionnaire (Serra, Aranceta, Ribas, Sangil, & Pérez, 2003).

Sagittal and frontal-plane videos (240 Hz) were recorded using a high-speed camcorder (Casio Exilim EXF1, Shibuyaku, Tokyo 151–8543, Japan). Videos were taken from a lateral view and a posterior view, with two cameras placed 5 metres from the runner so that he or she could be filmed in the sagittal and frontal plane, respectively. Filming location was set along a corridor of 5 metres. Video data were analysed using a 2D video editor (VideoSpeed vs 1.38, ErgoSport, Granada, Spain). The dependent variables selected for the kinematics analysis are in line with previous works (Hasegawa et al., 2007; Larson et al., 2011; Latorre Román et al., 2017) and are as follows: FSP at first contact with the ground, from rearfoot to forefoot: RFS, where initial contact is made somewhere in the heel or back third of the foot; Midfoot (MFS), where the heel and sole make contact almost simultaneously; and FFS, where initial contact is made with the metatarsal heads. Moreover, RPic (i.e., no INV/EVE) and no foot rotation in stance phase were considered. The RPic was observed in relation to rotation on the antero-posterior axis and was registered when the shoe contacts the ground in its central part; in addition, a strike pattern in which the first contact of the foot with the ground is produced by the lateral or medial edge of the foot was defined as INV and EVE respectively. No foot rotation was observed in relation to rotation on the vertical axis and it was registered when the shoe contacts on the ground following a straight line marked on the ground, furthermore, external and internal rotation (ER and IR, respectively) were analysed. Figure 1 shows pictures that illustrate the different variables. Moreover, asymmetries between the right and the left foot were also analysed in each of the above variables. The visual determination of the FSP has been used in other studies and, despite it is not as exact as the biomechanical determination, but it is practical for the assessment of a large cohort (Hollander et al., 2016). Running speed was measured using two double-light barriers (WITTY; Microgate Srl, Bolzano, Italy; accuracy of 0.001 seconds).

2.3. Procedure

In the current study the participants were asked to run, with their own shoes, at a self-selected running speed. Some indications were given to the participants: "Run comfortably. Don't run too fast and don't sprint". Additionally, the research team conducted a demonstration before testing, and the children performed some familiarisation trials on how to run. All participants ran for 40 metres to the recording area formed by a corridor 5 metres long by 2 metres wide. The running tests were performed on a flat, hard, non-slip surface, with the start line and finish line marked. Each participant performed two trials.

Table 1. Overall characteristics of participants.

	3–4 y Mean (SD)	5–6 y Mean (SD)	7–8 y Mean (SD)	9–10 y Mean (SD)	11–12 y Mean (SD)	13–14 y Mean (SD)	15–16 y Mean (SD)	p-value
Body height (m)	1.03 (0.06)	1.13 (0.06)	1.27 (0.06)	1.37 (0.06)	1.50 (0.08)	1.62 (0.08)	1.68 (0.09)	< 0.001
Body mass (Kg)	17.57 (2.86)	21.45 (4.45)	28.06 (5.41)	35.77 (8.90)	45.15 (12.15)	54.79 (11.97)	63.75 (12.04)	< 0.001
BMI (kg/m^2)	16.35 (2.04)	16.39 (2.67)	17.21 (2.56)	18.89 (3.76)	19.62 (3.91)	20.74 (3.35)	22.43 (3.56)	< 0.001
Physical activity (hours per week)	3.47 (2.41)	3.93 (3.36)	3.82 (2.02)	3.55 (2.57)	4.12 (4.18)	4.69 (2.48)	3.85 (2.38)	0.249
Running Speed (m/s)	2.15 (0.43)	2.31 (0.60)	2.83 (0.43)	3.10 (0.43)	3.23 (0.41)	3.12 (0.43)	3.37 (0.40)	< 0.001

y (years). SD (standard deviation). BMI (Body mass index).

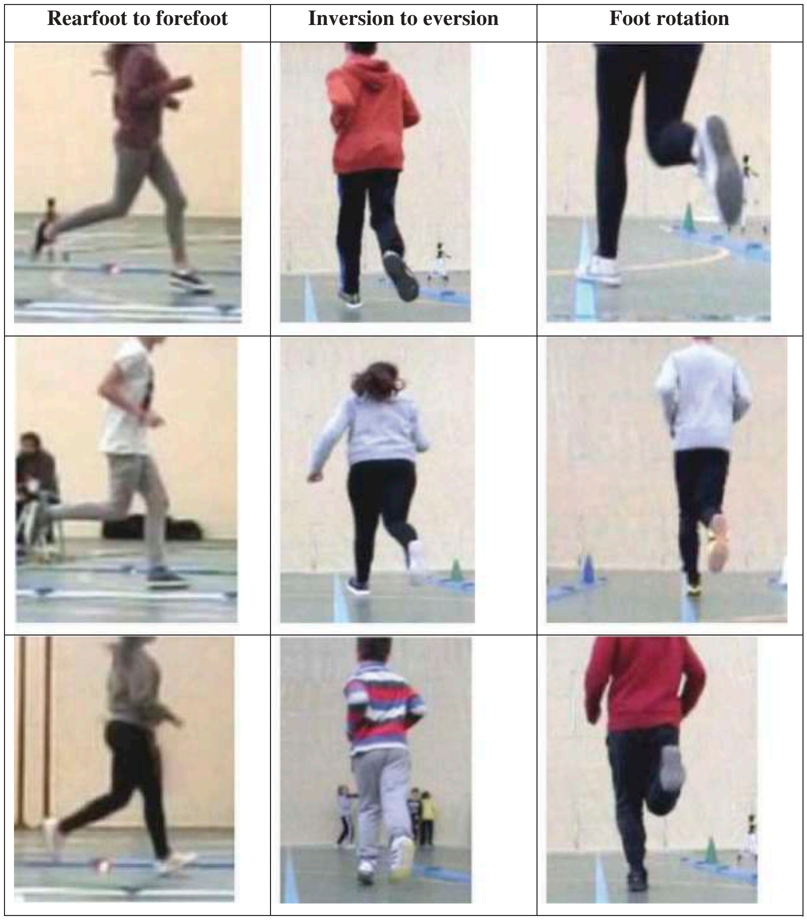

Figure 1. Examples of foot-strike patterns, foot rotation and rearfoot position at initial contact. From top to bottom and from left to the right. Foot strike patterns: forefoot strike, midfoot strike, rearfoot strike. Inversion, centered, eversion of the ankle. Foot rotation: external rotation, no rotation and internal rotation.

2.4. Statistical analysis

Data were analysed using SPSS, v.19.0, for Windows (SPSS Inc, Chicago, USA), and the significance level was set at $p < 0.05$. Descriptive statistics are represented as mean, standard deviation, frequency, and percentage. To analyse the differences of FSP, INV/EVE, and foot rotation between age groups, chi-square analysis was used; and to analyse the differences between quantitative variables, analysis of variance (ANOVA) was used. A binary logistic regression was used to determine whether age was significantly associated with RFS, RPic and no foot rotation (controlling for speed, BMI and sex as covariates). Odds ratios (ORs) are reported for significant associations. The predictive efficiency of age in RFS, RPic and no foot rotation were established by means of receiver operating characteristic (ROC) curves. In a sample of 50 participants, intra-observer reliability was calculated using Cohen's kappa and proportion of agreement for FSP, RPic, and foot rotation.

3. Results

The intra-observer reliability was obtained for FSP, kappa = 0.926, proportion of agreement = 98%. For INV/EVE, Kappa = 1.000, proportion of agreement = 100%. For the foot rotation, Kappa = 0.951, proportion of agreement = 98%. The average kappa value = 0.959 ± 0.03.

Table 1 shows the overall characteristics of the participants. There is a significant increase of anthropometric parameters when progressing through age groups. The initial foot contact in relation to RFS prevalence in age groups is shown in Figure 2. There is a significant increase ($p < 0.001$) of RFS prevalence in relation to age groups; e.g. preschool children (3–6 years old) displayed an RFS prevalence of 46.65% and the adolescents population (15–16 years old) an RFS prevalence of 92.20%. The total RFS prevalence in all samples was of 69.25%. Similar results are found in relation to FFS and MFS. There is a significant decrease ($p < 0.001$) of FFS and MFS prevalence in relation to age groups; e.g. preschool children (3–6 years old) displayed a FFS prevalence of 21.17% and MFS of 32.17% and the adolescents population (15–16 years old) an FFS prevalence of 5.9% and MFS prevalence of 1.8% (Table 2).

Figure 3 shows RPic in relation to age groups. There was a significant reduction ($p < 0.001$) of prevalence of RPic in relation to age groups; e.g. preschool children (3–6 years old) displayed a prevalence of RPic of 60.37% and the adolescents population (15–16 years old) 10%. The total

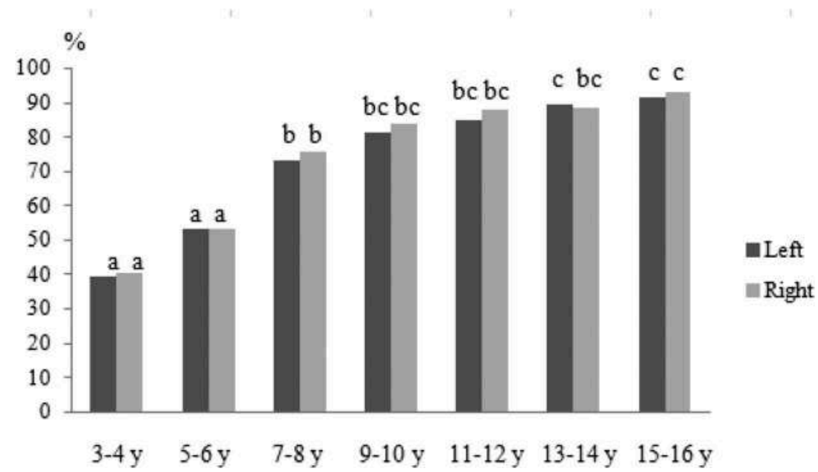

Figure 2. RFS prevalence in relation to age groups. Different letters indicate significant differences ($p < 0.05$) in relation to age groups.

Table 2. Foot strike patterns (FFS and MFS), INV/EVE and ER/IR in age groups Data are presented by n (%).

		3–4 y	5–6 y	7–8 y	9–10 y	11–12 y	13–14 y	15–16 y	p-value
FFS	Left foot	45 (24.1)$_{a}$	33 (17.7)$_{a, b}$	30 (24.4)$_{a}$	21 (16.3)$_{a, b}$	12 (11.2)$_{a, b}$	8 (7.0)$_{b}$	5 (5.9)$_{b}$	< 0.001
	Right foot	49 (26.2)$_{a}$	31 (16.7)$_{a, b, c}$	29 (23.6)$_{a, c}$	19 (14.7)$_{a, b, c}$	11 (10.3)$_{b, c}$	10 (8.7)$_{b}$	5 (5.9)$_{b}$	< 0.001
MFS	Left foot	68 (36.4)$_{a}$	54 (29.0)$_{a}$	3 (2.4)$_{b}$	3 (2.3)$_{b}$	4 (3.7)$_{b}$	4 (3.5)$_{b}$	2 (2.4)$_{b}$	< 0.001
	Right foot	62 (33.2)$_{a}$	56 (30.1)$_{a}$	1 (0.8)$_{b}$	2 (1.6)$_{b}$	2 (1.9)$_{b}$	3 (2.6)$_{b}$	1 (1.2)$_{b}$	< 0.001
INV	Left foot	33 (17.7)$_{a}$	25 (13.4)$_{a}$	102 (82.9)$_{b}$	107 (82.9)$_{b}$	89 (83.2)$_{b}$	93 (80.9)$_{b}$	70 (82.4)$_{b}$	< 0.001
	Right foot	36 (19.4)$_{a}$	20 (10.9)$_{a}$	106 (86.2)$_{b}$	107 (82.9)$_{b}$	100 (93.5)$_{b}$	100 (87.0)$_{b}$	81 (95.3)$_{b}$	< 0.001
EVE	Left foot	46 (24.7)$_{a}$	45 (24.2)$_{a}$	2 (1.6)$_{b}$	1 (0.8)$_{b}$	0 (0.0)$_{b}$	1 (0.9)$_{b}$	0 (0.0)$_{b}$	< 0.001
	Right foot	43 (23.1)$_{a}$	46 (25.0)$_{a}$	0 (0.0)$_{b}$	0(0.0)$_{b}$	0(0.0)$_{b}$	0(0.0)$_{b}$	2 (2.4)$_{b}$	< 0.001
ER	Left foot	77 (41.2)$_{a}$	73 (39.2)$_{a}$	99 (80.5)$_{b}$	102 (79.1)$_{b}$	95 (88.8)$_{b}$	88 (76.5)$_{b}$	75 (88.2)$_{b}$	< 0.001
	Right foot	72 (38.9)$_{a}$	76 (40.9)$_{a}$	64 (52.0)$_{a, b}$	87 (67.4)$_{b, c}$	81 (75.7)$_{c}$	81 (70.4)$_{b, c}$	68 (80.0)$_{c}$	< 0.001
IR	Left foot	22 (11.8)$_{a}$	21 (11.3)$_{a}$	3 (2.4)$_{a, b}$	2 (1.6)$_{b}$	1 (0.9)$_{b}$	1 (0.9)$_{b}$	1 (1.2)$_{a, b}$	< 0.001
	Right foot	22 (11.9)$_{a}$	17 (9.1)$_{a, b}$	10 (8.1)$_{a, b}$	9 (7.0)$_{a, b}$	4 (3.7)$_{a, b}$	2 (1.7)$_{b}$	3 (3.5)$_{a, b}$	< 0.001

Different letters indicate significant differences ($p < 0.05$) in relation to age groups.FFS: forefoot strike patterns. MFS: midfoot strike patterns. INV: Inversion. EVE: Eversion. ER: External rotation. IR: Internal rotation.

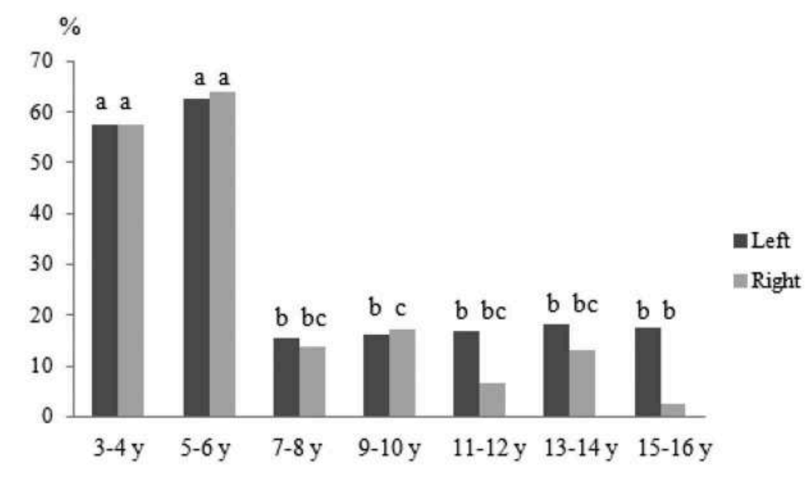

Figure 3. Prevalence of RPic in relation to age groups. Different letters indicate significant differences ($p < 0.05$) in relation to age groups.

prevalence of RPic in all samples was of 32.5%. Similar results are found in relation to INV and EVE. There is a significant increase ($p < 0.001$) of INV and a significant reduction ($p < 0.001$) of EVE prevalence in relation to age groups; e.g. preschool children (3–6 years old) displayed an INV prevalence of 15.35% and EVE of 24.25% and the adolescents population (15–16 years old) an INV prevalence of 88.85% and EVE prevalence of 1.2% (Table 2).

Foot rotation in relation to age groups is shown in Figure 4. There was a significant reduction ($p < 0.001$) of prevalence of no foot rotation in relation to age groups; e.g. preschool children (3–6 years old) displayed a

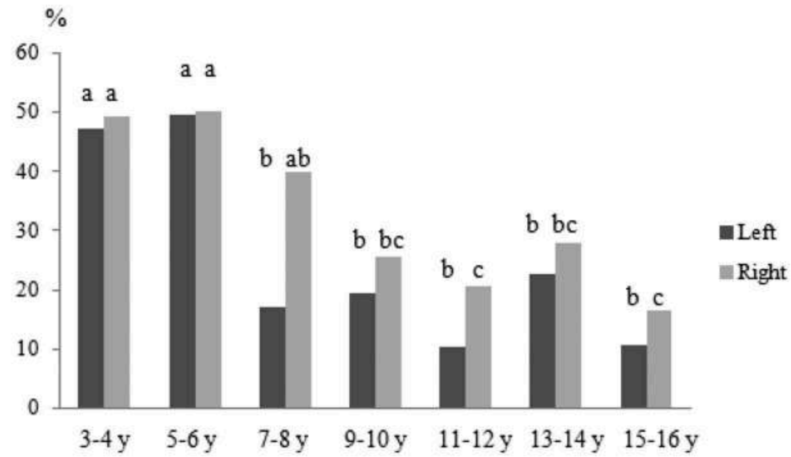

Figure 4. Prevalence of no foot rotation in relation to age groups. Different letters indicate significant differences ($p < 0.05$) in relation to age groups.

prevalence of no foot rotation of 48.95% and the adolescents population (15–16 years old) of 13.55% . The total prevalence of no foot rotation in all samples was of 32.55%. Similar results are found in relation to ER and IR. There is a significant increase ($p < 0.001$) of ER and a significant reduction ($p < 0.001$) of IR prevalence in relation to age groups; e.g. preschool children (3–6 years old) displayed an ER prevalence of 40.05% and IR of 11.02% and the adolescents population (15–16 years old) an ER prevalence of 84.1% and IR prevalence of 2.3% (Table 2).

FSP asymmetry is shown in Table 3. Preschool children displayed the highest asymmetry values in relation to RFS, INV/EVE and foot rotation. The prevalence of asymmetry in all samples in relation to RFS, INV/EVE and foot rotation was of 10.5%, 16.4% and 23.94% respectively.

The binary logistic regression analysis for the RFS points to age (Left foot, Odds Ratio = 1.204, 95% confidence interval (CI) = 1.086–1.336, $p < 0.001$; Right foot, Odds Ratio = 1,144, 95% CI = 1,028–1,272, $p = 0.013$) as a predictive factor. Figures 5 and 6 show the ROC curve of age-predicted RFS (Left foot, AUC = 0.752, 95% CI = 0.718–0.785, $p < 0.001$ Right foot, AUC = 0.758, 95% CI = 0.724–0.791, $p < 0.001$) with the cut-off point being 6.5 years for both feet. Age was not a factor to predict the RPic and no foot rotation.

4. Discussion

The main purpose of this study was to determine the foot strike patterns (FSP), RPic, and foot rotation in children in relation to age. The main finding is that the total RFS prevalence was 69.25%; this value is far below those found in adult runners (Kasmer et al., 2013; Larson et al., 2011; Latorre-Román et al., 2015). Moreover, as age increased the prevalence of RFS from 46.65% in preschool children to 92.20% in adolescents. Likewise, previous studies in children and adolescents showed that RFS prevalence in shod condition was 69.8–85.9% (Latorre Román et al., 2017; Mullen & Toby, 2013). Therefore, the authors suggest that children are originally FFS or MFS and transitioned progressively towards RFS, due to morphological/biomechanical changes associated with growth or due to the use of shoes. In this regard, a previous study showed that running biomechanics of preadolescent children are influenced by the use of footwear, especially by cushioned running shoes, eliciting significantly increased maximum and impact ground reaction forces, step length, step

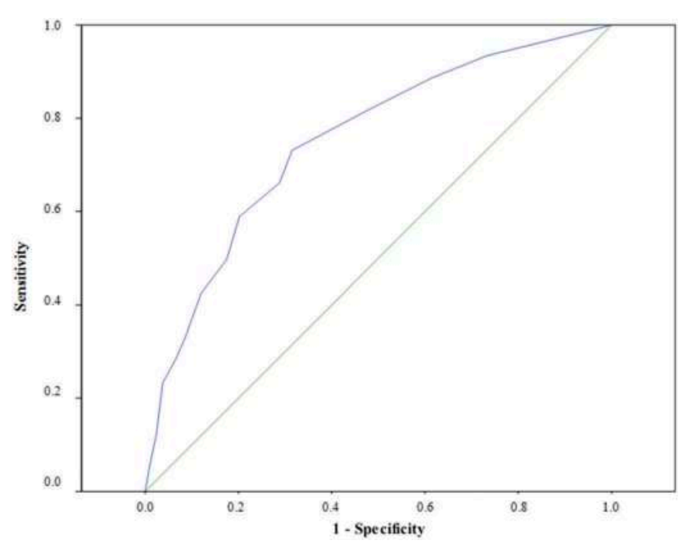

Figure 5. ROC curve RFS predicted by age (left foot).

Table 3. Asymmetry in FSP, INV/EVE, and foot rotation in relation to age groups (%).

	3–4 y	5–6 y	7–8 y	9–10 y	11–12 y	13–14 y	15–16 y	p-value
FSP	18.7 $_a$	17.2 $_{a,b}$	5.7 $_{b,c}$	5.4 $_c$	8.4 $_{a,b,c}$	2.6 $_c$	5.9 $_{a,\ b,c}$	< 0.001
INV/EVE	25.1 $_a$	15.7 $_a$	12.2 $_a$	14.7 $_a$	14.0 $_a$	11.3 $_a$	17.6 $_a$	0.020
Foot rotation	29.9 $_a$	30.6 $_a$	35.8 $_a$	29.5 $_{a,b}$	18.7 $_{a,b,c}$	11.3 $_c$	11.8 $_{b,c}$	< 0.001

FSP (foot strike patterns). INV (inversion). EVE (eversion). Different letters indicate significant differences ($p < 0.05$) in relation to age groups.

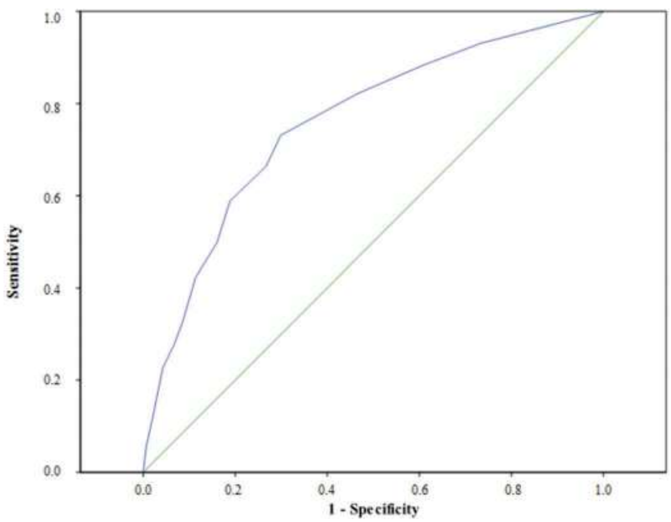

Figure 6. ROC curve RFS predicted by age (right foot).

width, and rate of RFS, which may pose an injury risk (Hollander, Riebe, Campe, Braumann, & Zech, 2014).

Therefore, there is an influence of footwear on the prevalence increased of RFS during childhood and adolescence. A previous study showed that, during running, shoes encourage RFS in children (Latorre Román et al., 2017). Moreover, several authors indicate that footwear could potentially be restricting the natural motion of the foot thus affecting its development; therefore, the shoes limit the motion of the foot in the forefoot region and not allowing it to spread under the load and utilise its structure (Franklin et al., 2015). Other authors showed that shoe-wearing in early childhood is detrimental to the development of a normal longitudinal arch (Bhaskara Rao & Joseph, 1992).

Accordingly, running biomechanics are significantly altered by shoe type in competitive adolescents, and thus heavily heeled cushioned shoes promote RFS; however, track flat shoes and barefoot running promote FFS or MFS, although it is not known whether these changes in FSPs may be detrimental to the adolescent runner who is still developing a running style (Mullen & Toby, 2013).

Another possible explanation of this finding is that increased step rate reduces the amount of RFS (Allen, Heisler, Mooney, & Kring, 2016). In this regard, Kampmiller, Vanderka, Šelinger, Šelingerová, and Čierna (2011) showed that there was high ontogenetic stability of the kinematics parameters during running in the population of 7- to 18-year-old youth, however, only in the prepubescent and beginning of the pubescent period at ages 11 to 15, the stride frequency reduces significantly, this relates to the rapid growth of body height and weight and the deterioration of biomechanical and coordination conditions of the organism. Therefore, children that displayed less stride frequency also could exhibit high RFS prevalence. In addition, typical barefoot/minimal-shoe runners showed a FFS gait and a high stride frequency (Muñoz Jimenez, García-Pinillos, Soto-Hermoso, & Latorre-Román, 2017; Perl, Daoud, & Lieberman, 2012). However, in the present study kinematics parameters were not recorded.

Other findings of this study were that the prevalence of RPic and no foot rotation are reduced as we progress in the age groups. The literature on RPic and foot rotation in initial contact during running is scarce. During the stance phase, it has been suggested that rearfoot eversion is associated with injury (Pohl, Mullineaux, Milner, Hamill, & Davis, 2008), and it is characteristic in shod runners (Murphy, Curry, & Matzkin, 2013). In addition, a previous study displayed that barefoot and minimalist running increased tibial internal rotation (Jonathan Sinclair, Greenhalgh, Brooks, Edmundson, & Hobbs, 2013). In current study, the prevalence of no foot rotation was similar than in the study of Muñoz-Jimenez et al. (2015) in long-distance runners.

Finally, kinetic asymmetries between both legs could expose one of the lower limbs to more stress and injury risk (Zifchock, Davis, & Hamill, 2006; Zifchock, Davis, Higginson, McCaw, & Royer, 2008); however, these studies showed no differences in asymmetry levels between injured and uninjured runners. Therefore, it is still unclear how kinematic asymmetry relates to overuse running injury. The data obtained in the present study indicated that the preschool children displayed the highest asymmetry values in relation to RFS, RPic and no foot rotation than adolescent population. The asymmetry prevalence in FSP was different from that found in the study of Muñoz et al., (2015) in adults' runners (RFS = 10.5% vs.3.9%, RPic = 16.4%% vs. 5.8%, no foot rotation = 23.94% vs. 37.7%).

Some limitations need to be addressed. First, the cross-sectional study design (i.e., FSP in growing children must be measured in longitudinal research). Second, the use of video analysis system to measure FSP, which is less accurate than a 3-D motion capture system. In this regard, the validity and reliability of visual determination of RPic and foot rotation should be confirmed in future studies. And third, footwear was not controlled nor assessed. Notwithstanding these limitations, the current study includes a large population sample of children, and, to our knowledge, it is the first study to determine the FSP in children according to age.

Wearing shoes predisposes to flat foot in children, because shoes inhibit the development of the arch of the foot due to lack of intrinsic muscle activity that is required for the development of the arch, leading to weakness of the intrinsic muscles. Therefore, it seems that footwear prevents the arches from developing their function (Ganesh & Magnani, 2016). In this study, the barefoot running style in relation to FSP, characterized by lower RFS prevalence (Latorre Román et al., 2017), is more usual in preschool children which, in part, could be due to the children being less influenced by years of using cushioned shoes. Although, the long-term effects of using cushioned shoes during growth on FSP and injury prevalence are currently unknown.

In conclusion, FSP in children are influenced by age, increasing RFS prevalence, and reducing the prevalence of RPic and no foot rotation as age increased. Finally, it is noteworthy that the RFS prevalence of children is lower in comparison to the adult population.

Disclosure statement

No potential conflict of interest was reported by the authors.

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