INTRODUCTION

Physical exercise is one of the most important health protectors and is recommended for the control of obesity [1,2], diabetes [3] and cardiovascular disease [4]. Hiking is one of the most popular and fastest-growing outdoor recreational activities [5]. However, the growing popularity of recreational hiking has increased the possibility of participants suffering injury or illness [6,7].

Walking, due to its low impact on the joints and high impact on cardiovascular disease prevention is a good aerobic exercise. However, biomechanical factors may provoke musculoskeletal problems [8] and dermal lesions may be caused by the use of inappropriate shoes or socks [9,10]. Blisters are the most frequent dermal lesions experienced during sporting performance, especially during hiking and related activities [11–14], and account for up to 64% of the medical complaints suffered by hikers [15]. Friction blisters result from pressure and shear forces causing delamination of the stratum spinosum [16], producing an accumulation of serous or bloody fluid.

The aetiology of foot blisters is diverse. Studies have identified risk factors such as friction at the skin and other interfaces, skin characteristics (moisture and hydration), biomechanics of the movement, characteristics of the activity and the characteristics of shoes and socks [9,17–23]. Foot blisters are not trivial injuries; they can be painful, restrict normal foot function and increase the risk of lower limb infection. Altered gait is a common strategy adopted to reduce pressure (and pain) in the area of the blister. However, this results in altered lower limb biomechanics and may increase the risk of secondary injuries during periods of extended or intensive exercise [24]. Blistering is one of the main causes of abandonment in competitions and of de- creased sports performance [25].

Surprisingly, only limited information is available about how to prevent blisters [26]. While the mere application of paper tape on the skin can provide an effective barrier [27], it is currently believed that skin moisture and hydration should be controlled through the use of appropriate socks, antiperspirants or barrier products to prevent injury [27,28]. However, the influence of the weight carried in a backpack, the use of new shoes or the type of terrain covered remains unknown. In view of the above considerations, the main aim of this study is to determine which factors influence the appearance of foot blisters during hiking, thus enabling those concerned to take appropriate measures to prevent the appearance or reduce the prevalence of foot blisters, and improve the quality of physical exercise.

METHODS

The study protocol was approved by the ethics committee of the XXXXX Xxxxx Xxxxxx (EC/18/255).

Design: cross-sectional study.

Participants

The sample consisted of 315 hikers (168 men, 147 women), who were examined for foot blisters in two hostels in the province of León, along the route of the Way

of St James (in northern Spain). The sampling method was convenience and consecutive. The inclusion criteria were patients receiving podiatry attention and who were aged at least 18 years, to walk at least 20 km in the last five days and to provide signed informed consent to take part in the study. Walkers who did not carry a backpack, who were pregnant or who had received surgical treatment of the lower limb or who had suffered musculoskeletal in- juries in the last six months were excluded. All participants were in- formed of the study goals. The data were collected anonymously and the ethical principles set out in the Helsinki Declaration (1964) were followed at all times.

Data collection

The participants' clinical and sociodemographic variables were collected during a clinical interview. All bullous lesions and their lo- cations on the foot were recorded. The participants' height and weight and the weight of the backpack carried were determined using an Astra® height rod (DH material medico, Spain) and weighing scale. The weight of their footwear was obtained with a digital scale.

Previous training was assessed according to the International Physical Activity Questionnaire [29]. Previous physical activity and level of fitness were categorised as the performance of walking, running, swimming, cycling, hiking or other physical activity. The weekly frequency was determined in each case.

The type of footwear was categorised as hiking boot, hiking shoe, hiking sandal, sports shoe or trail-running shoe. Note was taken of the existence and type of any waterproofing in the footwear (Goretex®, Novodray®, Waterproof®, other). A shoe was considered to be new if it had been used fewer than ten times; the length of use (in months) and the use of trekking poles was recorded.

The level of hydration of the skin was determined by asking whether the patient used cream or lotions daily and by ascertaining the daily intake of fluids. With respect to sweating of the feet, the participants were asked whether they used antiperspirants, or they experienced wet socks during the hike or at its conclusion. Note was taken of whether the hiker had changed wet socks for dry ones during the day.

The total distance walked on asphalt surfaces and on dirt trails, from the start of the hike to the podiatric care site, was calculated.

At all times, the study was conducted by qualified podiatrists with experience in sports medicine.

Data analysis

Quantitative variables are reported as means and standard deviations. Categorical variables are reported as frequencies, cross-tabulations and descriptive analysis. A foot scan was used to determine the position of the foot (neutral, pronate or supinate), according to the Foot Posture Index (FPI-6) [30,31]. The presence of custom made insoles within the footwear used was also recorded.

To determine the factors associated with the appearance of blisters, a bivariate analysis was performed, using the chi-square method for qualitative variables and Student's t test for the quantitative ones. Relationships between the variables were determined by logistic regression (odds ratios, OR).

A multivariate linear regression model was obtained to evaluate predictors of

injury. Goodness of fit was determined by evaluating the likelihood of the model with the chi-square test and by applying the AIC criterion. The explanatory capacity was assessed according to the Nagelkerke R2 coefficient. The significance level was set at $p < .05$.

All statistical analyses were conducted using SPSS v. 24.0 (SPSS Inc., Chicago, IL, USA. Finally, the predictive capacity was evaluated by calculating the sensitivity and specificity of the model and by determining the area under the receiver operating curve (ROC) and its 95% confidence interval.

RESULTS

The sample consisted of 315 participants (168 men, 147 women) with a mean age of 36.01 ± 14.13 years. The subjects had walked an average of 279.10 ± 211.06 km, of which 74.38 ± 50.13 km were on asphalt and 203.36 ± 162.80 km on dirt surfaces, for an average of
12.26 ± 9.53 days. The clinical and sociodemographic characteristics of the sample are described in Table 1.

65.9% (n = 207) of the participants had trained for this exercise during the previous months, with “walking” being the physical activity most frequently performed.

74% (n = 233) presented a bullous lesion on the foot after several stages of the hike. The areas most commonly affected were the toes (38.1%), followed by the metatarsal heads (especially the first and second), the heel and the fifth toe (Table 2).

The footwear most often used was the hiking shoe (by 38.1% of participants, n = 120), followed by hiking boots (19.7%, n = 62) and sports shoes (17.8%, n = 56). The footwear was new or had been used fewer than ten times for 38.7% (n = 122) of the participants. 41.9% (n = 132) used footwear with a waterproof lining despite the fact that the study was conducted in summer, when little rainfall was expected. The average weight of the footwear was 369.48 ± 114.83 gr. Hiking poles were used by 45.1% (n = 105) of the participants and the average weight of their backpacks was 7.63 ± 2.72 kg. The participants drank an average of 2.19 ± 0.87 L of fluids per day. Local hydration, by the application of creams and/or petroleum jelly, was used by 51.7% (n = 163).

47.9% (n = 151) of participants reported having had wet socks during the hike, but only 20.3% (n = 64) changed them for dry ones during the day and only 17.1% (n = 54) made daily use of anti- perspirants for the feet.

Calculation of the FPI for the right foot, revealed a pathological condition in 32.5% (n = 102) of the hikers, with pronation in 20% of cases (n = 63), very strong pronation in 1% (n = 3) and supination in 11.4% (n = 36). Similar data were obtained for the left foot; thus, the FPI was pathological in 29.3% of cases (n = 92), with pronation in 18.4% (n = 58), very strong pronation in 1% (n = 3) and supination in 9.8% (n = 31). However, despite the existence of these alterations, only 7.9% of participants (n = 25) wore plantar orthoses.

The bivariate analysis showed that the only statistically significant association

with the appearance of blisters was the use of plantar orthoses ($p = .002$) and the presence of wet socks at the end of the day's hike ($p = .004$). There was no association with the type of foot, the weight of the backpack, the hydration of the foot or the type of foot- wear used (Table 3).

Logistic regression analysis showed that the distance walked on asphalt ($p = .00$) [OR (1.019–1.064)] and the presence of wet socks at the end of the stage ($p = .006$) [OR (1.286–4.479)] were the main risk factors for the appearance of a foot lesion. On the contrary, the distance walked on dirt trails ($p = .00$) [OR (0.982-0.995)] and the use of custom made insoles ($p = .001$) [OR (0.085 -.512)] were protective factors (Table 4). Finally, the area under the ROC curve was 0.666 [OR (0.5956-0.7379)] (Fig. 1), which indicates that the model including these variables has a moderate capacity for predicting the appearance of foot blisters (Table 5).

DISCUSSION

The aim of this study is to determine which factors influence the appearance of foot lesions during long-distance hikes. We show that bullous lesions were present in 74% of the patients treated, which is in line with previous research findings [6,32]. The most frequent location of blisters was the fifth toe, which corroborates Choi [33], and the first and second metatarsal heads, on both feet. The prevalence of blisters was identical for male and female hikers, although some authors have reported a greater presence among women [12,34].

Regarding risk factors, we find, as do practically all previous studies in this respect, that moisture improves skin hydration but heightens the risk of blistering [35]. The application of powdered antiperspirants could have a barrier effect [28]. From our study results, it was not possible to determine whether the daily use of moisturising cream and/or an antiperspirant is a protective factor against injury, although the presence of wet socks at the end of the day's hike was observed to in- crease the risk of blistering. Therefore, we recommend changing socks at least once during the day, to keep the foot dry [9], and doing so more frequently if it rains.

We found no association between the position of the foot (pronate, supinate or neutral) and the probability of blisters. However, other studies have reported that the digital formula (squared for women and Egyptian for men) and the metatarsal index (plus/minus for women) may be related to a greater predisposition to dermal lesions [34].

Hoffman [9]recommended as a preventive strategy the use of custom orthoses and properly-fitting footwear. Plantar orthoses modify the gait pattern, improve the distribution of pressures and reduce friction and shear forces on the skin. Our results show that the use of plantar orthoses is a protective factor against injury, but it remains to be determined what type of material is most effective in reducing frictional forces [36]. Medium-density polyurethane materials may be most suitable for persons walking long distances on a hard terrain such as asphalt, due to their greater absorption capacity [36], while more rigid plastic materials such as polypropylene or carbon fibre could be more suitable when

hiking on softer, irregular terrain. The orthoses used, therefore, must be appropriate to the type of sports activity undertaken and the terrain on which it will take place.

The weight of the backpack may be an important factor in the appearance of paraesthesia in the lower limb [37], muscular alterations [38] or lumbosacral joint pain [39] but our study did not show this factor to be significantly associated with the presence of bullous lesions. However, the use of an excessively heavy backpack alters gait patterns, reduces dynamic stability and increases the risk of falls [40]. Therefore, it is recommended that the weight of the backpack should not exceed 14% of body weight, in order to avoid significant changes in ground reaction forces [41]. If the risk factors for the appearance of injury could be determined this would enable preventive measures to be introduced to reduce the incidence of pathologies, thus improving perceptions of physical activity and enhancing sports performance.

Limitations

In this study, the hiking route undertaken was long and the participants had walked for an average of twelve days. However, they were assessed at only two points along this route, and so the exact moment of the appearance of the lesion could not be detected. Some factors, such as the weight of the backpack, may have varied with respect to the starting weight, for example if items originally included were discarded during the hike. Another possibly significant factor is that the study was conducted during the summer, with average temperatures of about 20°. This circumstance may have influenced the appearance of injury.

We have no data about the influence of measurement quantitavive foot sweat related to the development of dermal injuries. Knowing the normal weight of the socks and comparing with final stage weight (sock + foot sweat) we might have obtained a good insight of the relationship of accumulated foot sweat quantitative with blisters formation. It is also essential to choose footwear according to the type of sur- face on which most of the hiking will be conducted. Although our study findings showed no relationship between the appearance of foot lesions and the use of a particular type of footwear (hiking boots, shoes or sandals), we opine that the choice of the sole material is important, because walking long distances on asphalt is known to increase the risk of injury, due to the hardness of the terrain and the higher temperature. [42]. The use of soles with damping systems that distribute pressures, or of ventilation channels that help lower the temperature inside the footwear, could minimise this risk.

CONCLUSIONS

Among the study participants, the most frequent location of foot blisters was the fifth toe. The type of terrain was a determining factor in the appearance of blisters, with less risk when the hike was conducted on dirt trails. The use of individual plantar orthoses and the control of humidity of the skin are other factors that should be taken into account as preventive measures. We recommend that hikers should be examined by a podiatrist before performing this activity.

The multivariate logistic model obtained has a moderate predictive capacity, as reflected by the ROC curve value of 0.666.

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