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The influence of sock composition on the appearance of foot blisters in hikers

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ABSTRACT

Introduction: Socks are of fundamental importance in reducing friction and in controlling the temperature and humidity of the foot, thus preventing the appearance of blisters. However, the influence of sock fibres (synthetic vs. natural) on blistering during long-distance hiking has received little research attention.
Aims: This study evaluates the influence of sock fibres on the appearance of foot blisters in hikers.
Method: The sample consisted of 203 male and female hikers, mean age 35.8 ± 14.5 years, from 22 countries. All were interviewed and assessed at shelters on the French route of the Camino de Santiago (Spain). Sociodemographic and clinical data were obtained for each hiker; other study data included the number of blisters on the foot, whether the socks were wet at the end of the day, the model of sock used and the nature of its constituent fibres.
Results: Among the hikers interviewed, 68.5% presented foot blisters. 74.2% used socks with predominantly synthetic fibres, compared to 25.9% whose socks were mainly composed of natural fibres. On average, they had walked 253.7 km. Hiking in wet socks was associated with a 1.94 times greater risk of experiencing foot blisters (95% CI 1.04–3.61) ($p = 0.035$). Multivariate analysis showed that the proportion of natural/synthetic fibres in the composition of the sock was not related to the presence of blisters.
Conclusions: The use of wet socks heightens the risk of foot blisters in hikers, but the composition of the sock is not associated with blistering. We recommend hikers change their socks in long stages to maintain feet dry and so avoiding the appereance of blisters.

1. Introduction

Socks are important items of protective clothing, both in everyday life and in energetic physical activity. Moreover, they can enhance biomechanical function, by increasing stability [1], improving confort and thermoregulation [2] and reducing pressure on the sole of the foot [3,4]. However, their main purpose is to protect the foot from friction with the shoe, preventing tissue damage and maintaining optimal conditions of temperature and humidity [5].

The Camino de Santiago, a long-distance hike normally completed on foot, is a low-intensity physical activity. Nevertheless, it is extensive in daily mileage and in total duration, up to 30 days [6]. In performing this aerobic activity, walkers generate a large increase in internal heat, which is manifested as an increase in skin temperature [7]. In the foot, this outcome is also influenced by the conditions of the foot-sock-shoe complex, which in conditions of darkness and the (more or less intense) occlusion produced by the sock fibres and the shoe material can provoke an excessive increase in humidity and temperature [8]. Foot temperature can also be influenced by the static or dynamic nature of the posture adopted [9] and by certain biomechanical variables, such as gait cadence, which is directly associated with the local temperature of the foot [10]. Thus, depending on the foot posture, certain areas may be warmer due to their greater participation in gait statics and dynamics [11].

During long-distance hiking, these conditions of excess heat and humidity can result in skin lesions, the most frequent of which are

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blisters, caused by continual friction between the sock and the skin. Moreover, the impact of this friction is aggravated by perspiration [12]. As the blister develops, the dermis and epidermis separate. This is followed by an accumulation of fluid (serum and/or blood) within the space created, causing intense pain [13]. Although the injuries produced are not usually very important, they can provoke antalgic gait (limping) and the appearance of further blisters (due to a change in the gait strategy), and may even force the hiker to stop walking, due to the pain experienced.

Improvements in the design of commercial socks, with the inclusion of special fibres incorporating copper oxide [14], chitosan [15] or bioceramics [16], can provide thermoregulatory benefits, reducing the degree of humidity and hence the likelihood of skin lesions. The addition of fluorine compounds [17] also alleviates the risk of dermatological pathologies such as plantar pustulosis. Nevertheless, few studies have considered the influence of the many fibres in current use (such as polyester, polyamide, polypropylene, cotton and wool) on the appearance of blisters, especially during long-distance hiking. Accordingly, the present study was undertaken to determine the type of sock fibre most frequently used by long-distance walkers and to determine the association between the composition of the socks, in terms of the fibres incorporated, and the prevalence of skin lesions (i.e., blisters) on the feet of hikers doing the Camino de Santiago trail.

2. Material and method

2.1. Participants

The sample consisted of 202 hikers (103 men; 50.7%, 100 women; 49.3%) with a mean age of 35.8 ± 14.5 years. The subjects were from 22 different countries, but 50.2% were Spanish, 21.7% Italian and 5.4% French. All were interviewed and assessed in shelters along the French route of the Camino de Santiago, in the province of León (northern Spain).

Participants in this study were selected according to the following inclusion criteria: all had attended podiatry consultation, had walked at least 25 km in the last five days, used boot or sport shoes trail, wore at least two repeated socks (same model and brand) and provided signed informed consent (in the case of minors, this was provided by the parent or guardian). The following were excluded: (a) hikers who attended the consultation without wearing socks; (b) persons who wore socks but not those most frequently used during the hike; (c) persons who had bought their socks during the route; (d) persons whose socks could not be identified by brand and model; (c) Participants who had wet socks because they had walked the day in the rain or cross areas with water. All participants were informed of the aims of this study. The data were collected anonymously and the ethical principles set out in the Declaration of Helsinki were followed in all respects. The study protocol of this cross-sectional study was approved by the research ethics committee of Miguel Hernández University (Code, EC/18/255).

2.2. Data collection

During the clinical interview, the following sociodemographic and clinical data for each participant were obtained: age, profession, nationality, fluid intake during the last stage and total kilometres walked. In addition, the height of each subject was measured (to the nearest millimetre) using a SECO 7710 calibrated portable measuring ruler with a spirit level attached to the arm for greater accuracy. Body mass and the weight of the backpack were measured to the nearest 0.05 kg using calibrated Digital Pegasus Scales, with the subjects wearing minimal clothing (T-shirt and shorts or skirt). The BMI was calculated from the subjects' height and weight (BMI = weight/height^2). The presence, number and location of bullous lesions (blisters) were determined by visual inspection. The presence of a blister was considered when we observed the existence of serous or bloody fluid with or without a break in the skin.

The condition of the socks was determined by asking each hiker whether their socks had been wet at the end of the day's hike and the examination performed by the clinician to detect the presence of humidity. The model of sock used was recorded and an internet search was subsequently conducted to determine the content and percentage of its fibres, according to the brand and model. The entire study was conducted by trained clinicians with experience in sports medicine.

2.3. Statistical analysis

The data for the study variables were normally distributed, as confirmed by the Kolmogorov-Smirnov test, and so the results obtained are reported as the mean and the standard deviation. In addition, a multivariable linear regression model was obtained to evaluate the predictors of blistering. In constructing this model, the regression assumptions of homoscedasticity, normality and independence of the residuals and collinearity were tested. Homoscedasticity was evaluated by analysing the distribution of predicted values and scatterplots of the residuals. Normality of the residuals was tested by analysing histograms and by plotting graphs of standardised residuals. Independence of the residuals was evaluated by the Durbin-Watson statistic. Finally, the presence of collinearity was tested by calculating the variance inflation factor, the tolerance and the partial correlations. The significance level was set at $p < 0.05$, with two-tailed tests. All statistical analyses were conducted using SPSS v. 24.0 statistical software (SPSS Inc., Chicago, IL, USA).

3. Results

Of the 203 hikers, clinical examination revealed the presence of bullous lesions in 139 (68,5%) cases. Mean number of blisters was 2.62 ± 1.90, being located at lesser toes (34.2%), followed by metatarsal zone (28.6%) and heel (27.1%). Their sociodemographic and clinical variables are detailed in Table 1.

In the vast majority of cases, the hikers' socks contained a variety of fabrics. 74.2% of the walkers wore socks containing mainly synthetic fibres, while 25.9% wore socks mainly composed of natural fibres. The types of fibre most frequently detected were elastane (synthetic), polyamide (synthetic) and cotton (natural) (Table 2).

With respect to the technical characteristics of the socks, only 68.5% of the participants used specific trekking socks, while 31.5% used running, tennis or fitness socks. 139 of the hikers presented foot blisters (mean: 2.6 ± 1.9) after having walked an average of 253.7 km. There was a significant relationship between the formation of blisters and the presence of wet socks ($p = 0.028$; OR: 1.9 [95% CI 1.07–3.6]). 52.5% of the hikers with blisters had wet socks at the end of the stage, and only 22.3% had changed them during the day.

A multivariate analysis was performed to determine whether the type and proportion of fibres in the composition of the sock was related to the presence of foot blisters (Table 3). In this respect, no significant relationship was observed (cotton, $p = 0.43$; wool, $p = 0.79$; polyamide, $p = 0.35$; elastane, $p = 0.137$; polyester, $0 = 0.11$; polypropylene, $p = 0.14$). Linear regression analysis revealed a Nagerkerker R^2 value of 0.74 (see Table 4).

Multivariate analysis also showed (confirming the bivariate analysis) that the use of wet socks during hiking multiplies the risk of foot blisters by 1.94 (95% CI 1.04–3.61) ($p = 0.035$).

4. Discussion

Socks are of fundamental importance in controlling the humidity of the feet, by conveying heat away from the skin and thereby ensuring proper hydration [18]. The quality and design of the sock fibres influence heat conduction from the foot to the sock [2]. Then, by contact, to the shoe, which produces convection (with the evacuation of sweat) and

Table 1
Sociodemographic and clinical variables.

Variables	With blisters N = 139				No blisters N = 64			
	Lower bound	Upper bound	Mean	SD	Lower bound	Upper bound	Mean	SD
Age (years)	15	78	35.2	13.9	15	80	38.6	15.3
Weight (kg)	47	105	71	12.9	46.5	95	71.5	13.8
BMI	15.9	32.1	24.2	3.4	17.9	32.8	24.2	3.6
Weight of backpack (kg)	1	18	7.8	2.6	1.5	15	7.6	2.5
Total distance hiked (km)	48	561.4	253.7	206.5	48	561.4	252.7	215
Fluid intake/day (litres)	1	5	2.3	0.8	1	4	2.1	0.7
Type of shoes	Boots 31% Trail shoes 29%				Boots 28% Trail shoes 12%			

Table 2
Composition of socks by type of fibre.

Type of fibre in the socks		Socks n (%)	Fibre content [Min-Max] n (%)	
Synthetic	Elastane	198 (97)	[1–25%]	
			0–50%	198 (97)
			51–75%	0 (0)
			>76%	0 (0)
Synthetic	Polyamide	189 (93.1)	[1–96%]	
			0–50%	63 (33)
			51–75%	21 (11)
			>76%	105 (55.6)
Natural	Cotton	61 (30)	[30–85%]	
			0–50%	20 (32.8)
			51–75%	27 (44.3)
			>76%	14 (23)
Synthetic	Polyester	45 (22.2)	[10–98%]	
			0–50	37 (82.2)
			51–75	7 (15.6)
			>76	1 (2.2)
Natural	Wool	20 (9.9)	[4–70%]	
			0–50%	10 (50)
			51–75%	10 (50)
			>76%	0 (0)
Synthetic	Polypropylene	13 (6.4)	[9–36%]	
			0–50%	13 (6.4)
			51–75%	0 (0)
			>76%	0 (0)
Synthetic	Lyocell	4 (2)	[33–36%]	
			0–50%	4 (2)
			51–75%	0 (0)
			>76%	0 (0)
Natural	Linen	1 (0.5)	7%	
			0–50%	1 (0.5)
			51–75%	0 (0)
			>76%	0 (0)
Natural	Viscose	1 (0.5)	27%	
			0–50%	1 (0.5)
			51–75%	0 (0)
			>76%	0 (0)

Table 3
Multivariate linear regression analysis. Association between blistering and the percentage of fibres in the composition of the socks.

Sock material content	B	p-value	β	95% C.I. for EXP(B)	
				Lower	Upper
Cotton	0.014	0.430	1.014	0.980	1.049
Wool	0.005	0.797	1.005	0.966	1.046
Polyamide	0.015	00.350	1.015	0.983	1.049
Elastane	−0.102	.137	0.903	0.790	1.033
Polyester	0.033	.111	1.033	0.993	1.076
Polypropylene	0.101	0.141	1.107	0.967	1.266

evaporation (by facilitating the exit of steam from sweating). Moreover, if the socks enable a better fit between the foot and the shoe, this could protect areas subjected to sustained hyperpressure, such as the central metatarsal heads [4,19].

Table 4
Multivariate linear regression analysis. Association between presence of blistering and the variables age, weight, sex, wet socks and application of anti-perspirant to the feet.

	B	β	p-value	95% CI Lower	95% CI Upper
Age	−0.017	0.983	0.107	0.962	1.004
Weight	0.004	1.004	0.795	0.976	1.032
Sex	−0.274	0.76	0.464	0.365	1.583
Wet socks	0.666	1.946	0.035	1.047	3.617
Application of anti-perspirant to the feet	0.039	1.039	0.941	0.372	2.902

Most previous studies in this area have focused on the need to design a sock that reduces pressure and friction and/or to improve the padding in areas that need more protection, and thus prevent the appearance of lesions [20]. However, the influence of the types of fibres used in the composition of socks has received little research attention, especially as concerns long-distance hikers and the blisters often suffered. Among the few investigations conducted in this respect, a study of long-distance runners reported that blisters were fewer and smaller when the socks used were made of 100% acrylic fibres rather than cotton [21]. Another study, by Knapik [22], considered a sample of US Marines and concluded that the incidence of blisters was lower in persons who wore wool and polypropylene socks over a sock with a polyester lining, compared to those who used socks composed of wool, cotton, nylon or spandex.

Socks made of merino wool have been shown to be cooler and to keep the skin drier than polypropylene-based socks [23]. However, wool stores more moisture, which might be a risk factor for developing blisters. In relation to coefficients of static/dynamic friction, fine wool presents lower values than acrylic fabrics [24].

In our study, the hikers' socks most frequently contained synthetic fibres, especially polyamide. Moreover, the percentage content of this polyamide was also very high, in many cases. However, although our analysis revealed an association between blistering and the use of wet socks, there was no significant relation regarding the type of fibre in the sock's composition. This is probably because other factors impact on hyperhydrosis, such as the use of shoes that do not 'breathe' [25], or high ambient temperatures or the shape of the foot [26,27]. Accordingly, the application of anti-perspirants to the feet could help prevent this type of injury to hikers [28], but further study is necessary to support this hypothesis, because to date little scientific evidence has been provided on their use for this purpose [29]. Other possible risk factors for blistering and other lesions include the weight of the backpack [30–32], the distance travelled, the type of terrain covered [33], the shear forces and pressure exerted [32] and the degree of hydration of the foot [33,34]. Wearing a sock composed of suitable fibres (especially those in contact with the areas of the foot at greatest risk of injury) and offering better temperature management could improve performance in

wet conditions and reduce the prevalence of injuries [35].

The present study has several limitations. (1) Sock wetness was determined by asking each hiker whether their socks had been wet at the end of the day's hike and also using the perception of the researcher, no objective parameters were used to measure it. (2) As the hike took up to 30 days to complete, it is likely that a range of different sock types could be used. But, even though we can claim as an inclusion criteria of a repeated model of socks were recorded, the different socks used could influence results. (3) Sock material was determined with an internet search to determine the content and percentage of its fibers, according to the brand and model, so it is uncertain which location in the socks these fibers were present, and contacted with areas in which the blister(s) developed. (4) The hikers wore hiking shoes/boots but it's uncertain for how long they wore them or how many kilometers they hiked before they changed their shoes.

5. Conclusions

The majority of hikers in our study population used socks made predominantly of synthetic fibres, especially polyamide, while only 25% used socks based on natural fibres. Hiking with wet socks (vs. dry socks) increases the risk of foot blisters, but the type of fibre in the sock's composition is not significantly related with the presence of these lesions. We recommend hikers change their socks in long stages, in order to maintain it dry and so avoid the appereance of blisters.

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