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Analysis of running technique and its influences on the architecture of the Achilles tendon

Análisis de la técnica de carrera y su influencia en la arquitectura del tendón de Aquiles

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Abstract

Introduction: the Achilles tendon is the most resistant tendon structure in the human body. Although it raises an injury prevalence of 24% within the population of runners, which increases exponentially at the international level. **Objectives:** we analyze the influence of the running technique on the architecture of the Achilles tendon, and we look for other factors that also influence its morphology. **Methods:** an observational, cross-sectional and descriptive study was carried out**;** thirty-three healthy habitual running subjects voluntarily participated. We carried out an orthogonal study of the tendon structure, obtaining values of diameter, perimeter, and microcirculation; the results were related to the runners' technique. **Results**: no significant differences were found regarding the influence of the running technique on the architecture of the Achilles tendon, observing that it was more significantly influenced by gender, height, and training. **Conclusions**: although the running technique does not influence the thickness of the Achilles tendon, the influence of the technique on other characteristics of the tendon should continue to be studied.

Keywords: ultrasonography, Achilles tendon, pathology, running.

Resumen

Introducción: el tendón de Aquiles es la estructura tendinosa más resistente del cuerpo humano. No obstante, presenta una prevalencia de lesiones del 24% dentro de la población de corredores, que aumenta exponencialmente a nivel internacional. **Objetivos:** analizamos la influencia de la técnica de carrera en la arquitectura del tendón de Aquiles, buscamos otros factores que también influyen en su morfología. **Metodología:** se realizó un estudio observacional, transversal y descriptivo, donde participaron voluntariamente treinta y tres sujetos sanos, corredores habituales. Se realizó un estudio ortogonal de la estructura del tendón, obteniendo valores de diámetro, perímetro y microcirculación y se relacionó con la técnica de los corredores. **Resultados**: no se encontraron diferencias significativas en cuanto a la influencia de la técnica de carrera en la arquitectura del tendón de Aquiles, observándose que influía más significativamente el género, la altura y el entrenamiento. **Conclusiones:** aunque la técnica de carrera no influye en el grosor del tendón de Aquiles, se debe seguir estudiando la influencia de la técnica sobre otras características del tendón.

Palabras clave: ultrasonografía, tendón de Aquiles, patología, carrera.

Introduction

The architecture of the Achilles tendon is capable of withstanding maximum forces that are estimated at 9 kN, even so, this structure is among the most frequent pathologies in runners with a prevalence of 10-27%[1,2] within a total prevalence of lesions of 53%.

The tendon is made up of bundles of collagen fibrils which are not organized strictly vertically, but instead are arranged in a spiral after the formation of the Achilles tendon, from the fusion of the soleus and gastrocnemius muscles. The tendinous bundles of the sural gastrocnemius insert on the posterolateral aspect of the calcaneus, while those of the soleus insert on the posteromedial aspect. The fusion point between the muscle bellies determines the rotation that this structure presents, fusion that is more distal results in more rotation, and vice versa.

The myotendinous and osteotendinous junctions are frequently critical points where injuries develop, it is especially vulnerable due to the possible torsional effect of the tendon during pronation[3]. Its most common pathology is usually of micro-traumatic origin with repetitive stresses of an eccentric nature[4].

In the context of running, tendinous fiber micro-ruptures occur because of repeated micro-traumatic mechanisms during running[2]. Together, the expression of several molecules appears, which promotes the tissue repair process, although due to tissue hypovascularity, the failure of the proliferative phase may occur, which causes some of these to now act as mediators of the disease, causing failure5,6. The neuronal growth that accompanies the neovessels explains the appearance of pain and triggers inflammation mediated by neurogenesis. Therefore, it is understood that inflammation and degeneration are not mutually exclusive processes, but are processes that occur during tissue repair processes, and if these fail, they are involved together in the pathogenesis of tendinopathies[7].

Histological characteristics of tendons in tissue repair processes have now been re-evaluated. In the initial tendinous injury phase, inflammatory infiltrations of B cells, T cells, macrophages, mast cells, and/or natural killer cells are characteristic6. Due to the low vascularization of the tendon tissue, the proliferation phase is compromised, if this fails, the tendon injury becomes chronic, with excessive activity of tenocytes appearing and changes in their morphology. The alteration of the collagen fibers, the increase in the non-collagenous matrix, such as glycosaminoglycans (GAG) and fatty tissue, as well as neovascularization. In addition, alterations in the expression of matrix metalloproteinases (MMPs) and their natural antagonists, tissue inhibitors of metalloproteinases (TIMPs), which regulate modeling and remodeling of tendons, are cleated to apparent dysmorphism in tendinopathy[5,8].

The presence of immune cells and inflammatory processes in tendinopathy are still under debate. Several studies deny the presence of inflammatory cells in chronic tendinopathy[9]. On the other hand, recent studies found inflammatory factors when studying a broader spectrum of tendons, about their stage of pathology[10]. That is why the hypothesis was recently formulated that inflammation is only relevant at the beginning of tendinopathy, during the acute phase, instead of in later stages where the inflammatory process has already disappeared from the lesional focus.

Chronic tendon pain is associated with increased neuromediators such as the neurotransmitter glutamate and glutaminergic receptors, substance P, and protein gene product 9.5 (PGP9.5), as well as an increase of inflammatory markers such as the group of differentiation (CD) 206 and CD45[11]. In addition, the pro-inflammatory cytokines cyclooxygenase-2 (COX2) and interleukin-6 (IL6) were shown to be upregulated in painful versus asymptomatic Achilles tendons[11].

In tendon pathology, ultrasound is the technique of choice in diagnosis, when the clinic is not decisive, reaching a reliability of 90-95%[12,13]. Acute tendinosis presents thickening and decreased echogenicity on ultrasound examination, while in chronic tendinosis, in which there is also thickening, areas of increased echogenicity may appear in the tendon[3].

Material and methods

An observational, cross-sectional, and descriptive study was carried out.

Recruitment

Recruitment of patients was carried out through the placement of posters in public areas and its dissemination through social networks.

Participants

Thirty-three healthy habitual running subjects voluntarily participated in the study. Participants of legal age were included, runners who performed at least two hours of weekly training and who were without current injury. Participants who could provide biased information were excluded: those who had undergone surgery or presented pathology in the lower limbs, or who had received corticosteroids in the previous 6 months. All participants received an information sheet on the objectives of the study, as well as informed consent and a questionnaire with to collect demographic and anthropometric data that they had to submit at the beginning of the study. All participants signed an agreement agreeing to the study and use of the data.

Design

All the measurements were collected in the first examination, in which the average of three measurements was used for the ultrasound measurements and the average of two measurements for the analysis of the running technique.

First, the ultrasound measurements of diameter and perimeter were collected through a standardized process, by an evaluator. Secondly, another evaluator collected the kinematic measurements of the race at the preferred speed of each runner and at a speed that increased the preferred speed by 50%, dividing the group of runners with the rearfoot hitting technique and the forefoot hitting technique, by the Runmatic app®[14].

Instrumentation

For the echographic measurements, the Ec graf was used. LogiqE BT 12 (General Electric, Germany) is equipped with a 12L-RS linear probe with a frequency of 5-13 MHz.

The Runmatic ® app is an app for Apple® devices. Thanks to this, we can measure, using an iPad Air device (A1566) on a BH Fitness F2W TFT treadmill (220/240V, 50Hz, 1654W), both kinetic and kinematic variables of the race. Apple cameras provide greater precision as they are capable of collecting 240fps. The application performs an analysis of the video, placing the moments of initial contact and takeoff of the foot during 8 steps, obtaining the data corresponding to the variables studied. In addition, a hydraulic stretcher, tape measure, and scale were used.

Process

An orthogonal study of the Achilles tendon was performed by ultrasonography with a multifrequency linear transducer and standardized transducer configurations (frequency=12 MHz, gain=46, DR= 93, penetration depth =3 cm, focus at 0.5 cm). During measurements, the patient was placed in the prone position with the feet dangling over the examination table and the ankle passively dorsiflexed to a neutral position. The Achilles tendon was examined longitudinally to determine tendon diameters at a reference point 2 cm proximal to the calcaneal insertion[15]. To calculate the cross-sectional area of the tendon[16], we placed the transducer 5 cm proximal to the tendon insertion on the bicipital tuberosity of the calcaneus, where the cross-sectional area of the Achilles tendon was calculated, in square millimeters. (mm2), maintaining the established ultrasound parameters. Finally, a PDI (power Doppler) scan was performed on the longitudinal and transverse image, observing the intratendinous blood flow present in the tendon. Power Doppler settings were frequency 8 MHz, pulse repetition frequency (PRF) 0.6 kHz, gain just below the level that causes noise artifacts, and low wall content. Doppler signal was scored 0 if absent, 1 if minimal (only 1 color point detected), 2 if moderate (2 points), or 3 if severe (≥ 3 points)[17].

To record running kinematic variables with the Runmatic ® app, a tripod was placed 30 cm from the side of the treadmill and held the iPad Air (A1566) in a vertical position at the same level as the floor of the treadmill, thus making a lateral recording at both speeds to show the location of the initial foot strike during 8 consecutive steps. By classifying runners as either rearfoot strike or forefoot strike, runners using a midfoot strike technique would be included in the forefoot strike group.

Blinding

An evaluator was in charge of performing the ultrasound measurement, unaware at all times of the results of the evaluation of the running technique. In the same way, another evaluator evaluated the running technique without knowing the data obtained by the ultrasound. At no time until the end of the study was any data provided to the subjects, both in the ultrasound and in the running technique.

Analysis

At the time of data management, the confidentiality agreement was maintained; the data obtained during the tests were entered into a database and each subject was assigned a case number. For the subsequent analysis of the results, the average values of the measurements made for each of the study variables were used. The statistical program IBM SPSS (SPSS v.19; IBM SPSS, Chicago, Illinois) was used, with a confidence level of 95%. For the description of the study subjects, means and standard deviations (SD) were used in the quantitative variables of age, height, weight, number of weekly training sessions, weekly training time, and number of years of practice. For the qualitative variables of sex, orthosis or bandage, type of terrain, injuries in the previous season, injuries in the current season, and surgeries, frequencies (n) and percentages (%) were used. The mean score for each measurement of tendon morphology was obtained from the three measurements made with the ultrasound scanner, these being used for the calculations that represent the final measurement (longitudinal diameter, transverse perimeter, and PDI). In addition, the data obtained, during video analysis with the Runmatic ® application were used to classify the subjects in the technique of forefoot (TGA) group or in the technique of rearfoot (TGR) group, for which the subject performed two tests and if its pattern was not clear, he would perform a third test to be able to classify it. Next, for the description of the morphology of the Achilles tendon within the study sample, means and standard deviations (SD) were also calculated. Next, to study the influence of the foot strike pattern in runners with the ultrasound architecture of the Achilles tendon, the homogeneity of the descriptive variables within both, TGA and TGR groups was studied, to subsequently study their differences in terms of Achilles tendon morphology using the T- Students test to compare independent means.

Results

The study sample consisted of 33 habitual runners between 18 and 51 years old. Table 1 describes the sample of runners, concerning their demographic characteristics (gender and age), anthropometric characteristics (height and weight), training quantification (number of weekly training sessions, hours of weekly training, number of years of practice and, type of terrain for which they train), and injuries (occurred in the previous season or in others and surgeries to which they have undergone).

In our study of the influence of the running technique on the morphology of the Achilles tendon, we studied the sample in two fundamental groups according to the initial striking technique of the foot during the race, thus dividing the group into the TGA and TGR. Later we studied the homogeneity between the groups of samples. Providing demographic and anthropometric data, related to the quantification of training, related to footwear and injury, which shows us an exhaustive vision in the description of the runner. In this way, we obtain a group formed by n=12 (36.4%) with TGA and another by n=21 (63.6%) with TGR. There are no significant differences between the two groups in these descriptive variables studied, obtaining as the lowest data p-value= 0.099 for age, finding TGA=29.42 (7.82) and TGR=34.48 (8. 42).

Table 2 describes the relationship between the structure of the Achilles tendon and the running technique using the student's test. We show the results obtained from the comparison of both groups described above, looking for associations with the architecture of the Achilles tendon. In this way, the means and standard deviation of both, the diameter of the tendon in the longitudinal view and the perimeter in the cross-sectional view are shown. Finally using the Shapiro-Wilk test for sample homogeneity, we obtain the relationship between both variables.

Regarding the measurements of diameter and perimeter, both in the right and left Achilles tendons, there are small mean differences that tend towards an increase in thickness in the forefoot striking technique (table 2). However, these differences are not significant and there is not a clear relationship between these variables. On the other hand, the spectrum of the percentiles of tendon thickness makes us think that other variables could be affecting tendon morphology.

Discussion

In this work, we have studied the relationship between the striking techniques during the race with the morphology of the Achilles tendon. For this, it was important to study how the descriptive variables of the population of runners are present within both groups of running techniques. There was not any significant difference in terms of the distribution of subjects in variables such as age, sex, and anthropometric data, not even in terms of the quantification of their training, presenting averages of 3.67 hours per week of training in TGA and 4.29 hours on TGR. It is of great importance in this case to quantify the training, as revealed by the investigations of Legerlotz et al[2] and Eliasson et al[18], in their studies of the morphology and biomechanics of the Achilles tendon in mice, or the studies of Magnuson et al[19], in runners, mechanical stress generates adaptations in the tissues to efficiently carry out the stress for which they are being required.

Table 1. Characteristics of the study sample

Characteristic		Results
Demographics	Gender male: n (%)	29 (87.9%)
	Age in years: mean(SD)	32.64y (8.45)
Anthropometric	Height in m: mean(SD)	1.74m (0.08)
	Weight in kg: mean(SD)	74.77 (11.72)
Training	Number of weekly workouts: mean(SD)	3.21 (1.19) range 2-6
	Weekly training time in hours: mean(SD)	4.06 (2.52)
	Number of years of practice: mean(SD)	7.56 (7.78) range 1-30
	Terrain type regular: n(%)	17 (51.5%)
Injuries	Previous season: n (%)	13 (39.4%)
	Other seasons: n (%)	19 (57.5%)
	Surgeries: n (%)	7 (21.2%)
Characteristics of AT	Left AT diameter in cm: mean(SD)	0.52 (0.09)
	Right AT diameter in cm: mean(SD)	0.52 (0.1)
	Right AT perimeter in cm2: mean(SD)	0.52 (0.1)
	Left AT perimeter in cm2: mean(SD)	0.59 (0.14)

AT: Achilles Tendon

Source: original from authors.

Table 2. Relationship of tendon architecture with running technique

Study variable	Hemibody	Career technique		Shapiro-Wilk
		Forefoot	Hindfoot	p-value
Diameter (SD)	Left	0.53 (0.09)	0.51 (0.09)	0.656
Diameter (SD)	Law	0.54 (0.12)	0.5 (0.10)	0.258
Perimeter (SD)	Left	0.54 (0.14)	0.5 (0.13)	0.264
Perimeter (SD)	Law	0.57 (0.16)	0.6 (0.12)	0.523

Note: The data corresponding to diameter measurements are provided in centimeters and the data corresponding to the perimeter in square centimeters; SD: standard deviation.

Source: original from authors.

Regarding the relationship between the thickness of the tendon and the hitting pattern during the race, we obtained data on mean increases in the thickness of the tendon, both in the measurements of the diameter in the longitudinal section and the perimeter in the cross-section, in the technique group of forefoot strike (TGA), except in the perimeter of the right TA, although no significant differences appear in any parameter analyzed.

Although a forefoot strike strategy during the race demonstrates an increase in the request of the Achilles tendon, implying this increase in the mechanical stress of the tendon, is an adaptation to efficiently solve the functions for which it is required. There does not seem to be an adaptation of the morphology of the tendon in terms of the thickness of the tendon neither the diameter in the longitudinal section nor the perimeter in the cross-section. Although there may be other characteristics of the tendon architecture that are adapted to withstand the greater mechanical stress caused by TGA in the Achilles tendon.

Other studies such as the one by Ríos-Díaz et al[20] explored the echogenicity of the tendon in terms of the mean gray level, dispersion, gray level variations, coefficient of variation, and second angular momentum or energy, finding significant differences in the comparison between the dominant and non-dominant limb. Being a population of athletes, they conclude that the mechanical stress endured in eccentric tension by the Achilles tendon may be the cause of these changes.

Entropy could also be explored in future studies, variables that are already being tested in terms of reliability and reproducibility, giving non-significant variability results, which makes them potential measurement techniques for the orthogonal study of the tendon structure[12,21].

On the other hand, studies carried out with tendinous tissue in rats can guide us toward the physiology of this structure over time and in response to different stimuli[2,18]. Using mechanical studies (study of resistance) and observation with microscopic techniques of the tendinous structure, such as polarization microscopy with birefringence and linear dichroism techniques[22], we could obtain information on the composition and organization of the extracellular matrix, to generate knowledge for the synthesis of hypotheses that can be extrapolated to human individuals, both for the understanding of the physiological process of this structure and for the therapeutic approach during the pathology.

Possibly, as other authors have already described[22,23], there is no relationship between the increase in the strength and resistance of the tendon due to physical activity and the increase in the concentration of collagen fibers. They justify the increase in the thickness and area of the tendon by an increase in the water content of the extracellular matrix, other non-collagenous type fibers and perhaps newly synthesized matrix, as occurs during the pathological process of tendinosis[6,7], or other non-tendon processes that imply physiological and anatomical differences between individuals such as age, sex, heigh[3,24], as well as changes in basal hormonal levels or diabetic processes[22] present changes in the tendon structure.

After studying the sample of runners, and as an objective conclusion raised in our research, we concluded that the foot strike pattern does not have a statistically significant influence on the thickness of the Achilles tendon in runners. However, this variable may affect other characteristics of the tendon.

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