# ANTERO-POSTERIOR ADJUSTMENT OF THE CLEAT WITH REGARD TO THE LOWER LIMB FOR ROAD CYCLING


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## ABSTRACT

The aim of this work is to determine the antero-posterior position of the cleat based on various morphological characteristics of the cyclist. The pedal/shoe connection is a crucial element, as many of the non-traumatic lesions to the cyclist's lower limb are caused by a poor fit between the two, so that it is important to study their relationship. Two tests were used to quantify this position: a photograph and a radiograph, which were digitalized to enable measurements using the program AutoCAD® 2006. Two linear regression models were constructed from the variables cleat/first metatarsal distance and tip/cleat distance, which were invalidated by the low R2 coefficient value (0.106 and 0.057 respectively). All the cyclists presented almost constant values of 3.6 ± 0.8 cm for the cleat/first metatarsal distance and 0.43 for the tip/cleat distance; as the distance from the base of the cleat to the pedal spindle is 3.6 cm. We can state that by positioning the base of the cleat at 43% of the length of the shoe measured from the tip, we are making the pedal spindle coincide with the head of the first metatarsal.

## INTRODUCTION

The most common lesions in cyclists are those affecting the knee, some 25% of all the non-traumatic injuries suffered [(1, 2)]. They can affect cyclists of any category, but are most frequent among those of a high level, because of the substantial kilometrage they cover in training [(3)]. Such lesions can range from slight discomfort on going down steps or after a long ride, to the impossibility of pedaling. There have been few data recorded during recent years on the incidence of discomfort in cyclists' knees. The most frequent types of lesion from overloading in cycling result in femoropatellar or latero-medial pain in the knee joint [1, 3-5]. Different research aimed at preventing possible lesions [6, 7] has analyzed the elements giving the most exact alignment in the fit between cycle and cyclist for each rider. The height of the saddle and handlebars and the length of the crank are the most common, but there is nothing with regard to the exact position of the cleat on the shoe. Cycling lesions can also be due to misalignments between cyclist and cycle. It must be remembered that the pedal restricts the foot to a circular pattern in the sagittal plane, and that the shoe/pedal fixing systems do not allow movements of the two parts in the three planes (although some pedals allow slight movements in the transverse plane). If the segments of the lower limb do not describe a normal trajectory during pedaling, the forces generated in pedaling add loads to the joints that are not associated to the propulsion of the cycle [8]. An incorrect anterior-posterior position affects the anterior-posterior forces of the knee [9-11].

The shoe/pedal interaction is critical for an effective transmission of the forces generated by the cyclist to the cycle, so that the alignment of these parts is considered an important factor in the management and treatment of lesions caused by overloading at the level of the knee[12]. Currently there is no consensus on the ideal longitudinal position of the cleat to prevent possible lesions, while some authors refer to an adjustment based on the coincidence of the pedal spindle with the head of the second metatarsal [9, 11, 13, 14], others claim it should be with that of the first metatarsal [7, 15, 16].

This work is designed with the following aims: (1) to analyze the exact position of the cleat with regard to the variables studied for each cyclist, (2) to determine which of the longitudinal variables presents the greatest importance in the adjustment, and (3) to construct regression models enabling adjustment of the position of the cleat for each cyclist from anthropometric variables. The null hypothesis of this study is that there is not one position of the cleat for each cyclist with regard to the variables of the lower limb.

## METHODS

The target population of our study comprises cyclists who use an automatic pedal and practice the sport intensively. The sample size was calculated with the program nQuery Advisor 4.0, using the number of variables to relate (between 2 and 5), the expected values of the coefficient of multiple correlation (ranging between 0.14 and 0.68 in a pilot study), a value for $\alpha$ of 5%, and a $1-\beta$ power of 80%. These data gave a size of 88 feet. The sample comprised 44 individuals (88 lower limbs: 44 right and 44 left), of which 7 were women and 37 men, with a mean age of 34.4 ± 11.1 years. Each participant gave written consent to take part in the study, which was approved by the Experimental Ethics Committee of the University of Seville.

We think it opportune to point out that references are always to lower limbs rather than to persons, as the anthropometric variables of the two extremities (right and left) may be different in the same individual, and in clinical practice the need to perform a separate evaluation for each foot is very frequent. As Menz and Munteanu explain [(17)], the main conceptual and statistical problems generated by this type of approach arise when the inferences derived from the studies are made in relation to persons, having used the extremities as the unit of analysis. As the aim of this study is to analyze and relate the characteristics of the lower limb and the cleat, we used as unit of the sample the lower limbs, and not the individuals; thus, we consider the sample to comprise 88 feet.

Creemos conveniente señalar que se hace referencia siempre a extremidades inferiores, en lugar de a personas, ya que las variables antropométricas de las dos extremidades (derecha e izquierda) pueden ser distintas en un mismo individuo, y en la práctica clínica es muy frecuente la necesidad de realizar una valoración independiente para cada pie. Como explican Menz y Munteanu [17], los principales problemas conceptuales y estadísticos que generan este tipo de planteamientos ocurren cuando las inferencias derivadas de estos estudios se hacen con respecto a las personas, habiendo utilizado las extremidades como unidad de análisis. Puesto que el objetivo de este estudio es analizar y relacionar las características de la extremidad inferior y la cala, utilizamos como unidad de la muestra los miembros inferiores, y no los individuos, por lo que consideramos que la muestra estuvo constituida finalmente por 88 pies.

The criteria for inclusion in this study were the following: cyclists aged more than 20 years old [18-25], not having suffered severe traumatisms to or surgical operations on the lower limb, not having suffered lesions caused by overloading the lower limb during (at least) the previous year, using automatic pedals Look®, and with a sporting intensity of a minimum 5.000 km annually.

The variables were recorded using two tests: a photograph and a radiograph, both under a protocol designed so as not to alter the measurements from one subject to another. For the first, a Cyber-shot DSC-P120 digital camera (Sony, San Diego, U.S.A.) was used, with a resolution of 5.1 megapixels and an optical zoom capacity of 3x, placed on a tripod at a distance from the ground of 1 meter, completely vertical to the shoe, which was resting on the ground and centered on the screen such that the tip and the heel of the shoe exactly fitted the image frame. The dorsoplantar radiographs were made with an inclination of 15 degrees of the X-ray tube to the vertical [26] and with a tube/plate distance of

1 meter, in accord with the criteria of the Measurements and Terminology Committee of the AOFAS [27, 28] (*American Orthopaedic Foot and Ankle Society*). All the radiographs were taken with the foot load-bearing, as this is the constant state of the foot in this sport [29]. The radiological parameters employed were 65 Kv and 10 mAs. Because of the radiotransparency of the piece under study (the cleat), it was decided to place a rigid metal element at its base to act as a reference in the image of the angle of the shoe when fixed on the pedal (FIGURES 1 and 2).

The radiograph thus obtained was digitalized, using a scanner able to explore images on negative films (EPSON EXPRESSION 1680 Pro®, Seiko Epson Corporation, Nagano, Japan) to create a digital image. Measurements were made on the digital image, using the software AutoCAD® 2006 (Autodesk Inc, San Rafael, California). The protocol of digitalization and measurement of the radiographs has previously been used in other studies [30-35].

The variables studied were age, gender, annual distance ridden (km), weight, height, body mass index (BMI), angle of adduction of the forefoot, metatarsal formula,[36, 37] shoe size, distance between the cleat and the first metatarsal, and distance between the tip of the shoe and the base of the cleat.

The angle of adduction of the forefoot was measured on the cyclist's radiograph. It was formed by the intersection of the longitudinal axis of the second metatarsal with that of the tarsus minor [38-41][40, 41]. The cleat/first metatarsal distance (FIGURE 3) was measured on the radiograph, as the distance from the first metatarsophalangeal joint to the base of the cleat. The tip/cleat distance (FIGURE 4) was measured on the photograph, as the ratio between the distance from the tip of the shoe to the base of the cleat and the total length of the shoe.

The data analysis was performed using the software SPSS 15.0 for Windows. The intraclass correlation coefficient for the reliability of the measurements was calculated, using 10 randomly chosen cases from the sample, measured 3 times at intervals of a week. A statistical purification was performed to detect atypical values. The Kolmogorov-Smirnov test was used to check whether the data followed a normal distribution; the results of this test showed a normal grouping of the data, validating the use of parametric tests. A Student´s t-test for independent samples was performed on the dependent variables depending on the laterality (right-left) to test the homogeneity of the sample. Lastly, multiple linear regression models were constructed using the cleat/first metatarsal distance as dependent variable in one model, and the tip/cleat distance in another model, and shoe size and metatarsal formula[36, 37] as predictor variables. The value of p was considered significant when below $p \leq 0.05$.

## RESULTS

In this study, a total of 44 cyclists took part (88 feet), of whom 7 were women and 37 men. The values for the variables age, weight, height, BMI, and annual km are shown in TABLE 1.

**TABLE 1.** Descriptive variables of the sample

| | N | Minimum | Maximum | Mean | Typ. Dev. |
|---|---|---|---|---|---|
| Age (years) | 88 | 19.00 | 62.00 | 34.41 | 11.09 |
| BMI | 88 | 18.62 | 26.99 | 23.20 | 1.92 |
| Height (m) | 88 | 1.57 | 1.84 | 1.72 | 0.08 |
| Weight (kg) | 88 | 52.00 | 84.00 | 68.79 | 7.92 |
| Annual km (km) | 88 | 5000 | 30000 | 12470.45 | 6243.58 |

For the qualitative variable metatarsal formula(36, 37), there were 26 cases of plus index, 60 of minus index, and 2 of plus-minus index. The shoe size presented minimum and maximum values of 39 and 46 respectively (measured as Paris Points). For the remaining variables, the mean, the typical deviation, and the lower and upper limits for a confidence interval of 95% are detailed in TABLE 2.

**TABLE 2.** Mean, typical deviation, and confidence interval to 95% for the quantitative variables.

| | | **Confidence interval to 95%** | |
|---|---|---|---|
| **Variable** | **Media ± DT** | **Lower limit** | **Upper limit** |
| Angle of adduction of the forefoot (º) | 13.3 ± 0.4 | 12.4 | 14.2 |
| Cleat/I-metatarsal distance (cm) | 3.6 ± 0.8 | 3.4 | 3.7 |
| Tip/cleat distance (%) | 0.43 | 0.42 | 0.43 |

The results of the Student´s t-test for independent samples on the dependent variables depending on the laterality did not show significant differences in the sample, or in the variable cleat/first metatarsal distance (p = 0.251), or in the tip/cleat distance (p = 0.246).

The linear regression was intended to illustrate the effects of the independent variables on a dependent variable, so that two models were constructed depending on whether the dependent variable was the cleat/first metatarsal distance or the tip/cleat distance.

**CLEAT/FIRST METATARSAL DISTANCE MODEL**

The values of R and $R^2$ for this first model were 0.326 and 0.106 respectively, with p = 0.002. The multiple linear regression procedure (TABLE 3) yielded the following formula for the determination of the position: ***first metatarsal distance = -22.624 + (1.379 · shoe size).***

**TABLE 3.** Coefficient of correlation of model 1

| **Model** | **Non-standardized coefficients** | | **Confidence interval for B to 95%** | |
|---|---|---|---|---|
| | B | Typ. Error | Lower limit | Upper limit |
| Constant | **-22.624** | 18.240 | -58.884 | 13.636 |
| Shoe size | **1.379** | 0.431 | 0.522 | 2.236 |

**TIP/CLEAT DISTANCE MODEL**

The values of R and $R^2$ for this second model were 0.238 and 0.057 respectively with p = 0.025. The multiple linear regression procedure (TABLE 4) yielded the following formula for the determination of the position: ***tip/cleat distance = 0.618 – (0.005 · shoe size).***

**TABLE 4.** Coefficient of correlation of model 2

| **Model** | **Non-standardized coefficients** | | **Confidence interval for B to 95%** | |
|---|---|---|---|---|
| | B | Typ. Error | Lower limit | Upper limit |
| Constant | **0.618** | 0.084 | 0.450 | 0.785 |
| Shoe size | **-0.005** | 0.002 | -0.008 | -0.001 |

**DISCUSSION**

The adjustment of the cleat is a possible risk factor in the development of knee lesions caused by overloading. The incidence of this type of lesion is very high — of the order of 25% [2, 42] — and its etiologies have still not been described clearly. Although numerous adjustments exist between cyclist and machine, there are no accepted scientific criteria for the positioning of the cleat. With this work we have attempted to contribute by establishing individualized criteria that help in adjusting the cleat to avoid this type of lesion. Furthermore, the results could be used to establish specific adjustments of the cleat for the rehabilitation of certain lesions to the lower extremity.

Ericson et al. [9, 11, 13] studied the changes of moment produced in the lower limb when the position of the cleat was altered, and established two positions, an anterior one, in which the pedal spindle coincides with the head of the second metatarsal, and the other posterior, 10 centimeters behind the first. They found that the anterior position generated an increase in the dorsiflexion of the ankle (by five degrees), in the moments of the ankle, and in the activity of the soleus. In contrast, the rearward position of the cleat produced an increase of seven degrees in the movement of the hips and of three degrees in that of the knee, and increased the stress suffered by the anterior crossed ligament. Mandroukas [14] also studied the repercussions in the lower limb of cleat displacements, and found that pedaling was more effective with an anterior position of the cleat.

Contrary to the foregoing, different authors recommend placing the cleat such that the spindle coincides with the head of the first metatarsal. Vey Mestdagh [7] emphasizes the importance of determining the exact position of the cleat on the cyclist's shoe, because for the lever formed by the midfoot and rearfoot to be useful, the pedal spindle must be positioned under the head of the first metatarsal. Callaghan [16] and Ruby [15] maintain that the most commonly accepted position for the foot in relation to the pedal is an alignment of the head of the first metatarsal with the pedal spindle.

Sanderson et al. [43, 44], who analyzed the distribution of plantar pressures during pedaling, discovered that as the resistance increased the zone comprising the head of the first metatarsal and the first toe bore an increased percentage of load. Moreover, it has to be taken into account that the anterior-posterior position of the foot (together with the height of the saddle) alters the length of the lower extremity.

In the present work two models of linear regression have been constructed one based on measurements from a radiograph, and the other on those from a photograph. In the first based in the dependent variable cleat/first metatarsal distance and using the metatarsal formula[36, 37, 45] and shoe size like independent variables, the value of $R^2$ indicated that the model was not very useful, so it was rejected, allowing the statement that the longitudinal position of the cleat will not be affected by either the type of metatarsal formula[36, 37] or the cyclist's shoe size. All feet, independently of the type of metatarsal formula[36, 37], presented very similar values for the cleat/first metatarsal distance, whose mean was 3.6 ± 0.8 cm and in this type of pedal, the spindle is always 3.6 cm from the base of the cleat. This means that there is a constant for the position of the cleat with respect to the head of the first metatarsal, in accord with the studies of Sanderson [43, 44], Ruby[15], and Callaghan [16]. There is the same distance from the base of the cleat to the head of the first metatarsal and to the pedal spindle, so it tends to be a constant.

In the second model, based on the tip/cleat distance, we used the same independent variables (metatarsal formula[36, 37] and shoe size). This model yielded $R^2$ values even lower than the first, meaning that the relative position of the cleat does not vary with the shoe size. From the data of the variable tip/cleat distance, the mean value was 0.43, and because we confirmed in the first model the effect of the spindle over the head of [36, 37] the first metatarsal, we can place the cleat exactly, multiplying the constant 0.43 (variable tip/cleat) by the length (in cm) of the cyclist's shoe, so that the pedal spindle will lie over the head of the first metatarsal. These data are in accord with those obtained by González and Hull [46], who determined that the ideal position is when the cleat is at 54% of the length of the shoe measured from the rearfoot that is, at 46% from the tip. This could be used in future works to create a table with the exact distance from the tip for each shoe, thereby avoiding possible lesions caused by a poor adjustment, such as overloading of quadriceps (in the case of a rearward position) or of gemelli (in a forward position) [7], and excessive tension in the knee ligaments [47]. Another practical implication of the results of this study could be their application to help in techniques of rehabilitation — thus, knowing the position of the cleat for a particular cyclist, the tension of a damaged Achilles tendon could be regulated using the results of the study by Ericson et al. [48]; or working the dorsiflexion of a posttraumatic ankle by moving the cleat rearward to a greater or lesser extent; or helping in the rehabilitation of a knee with a lesion of the anterior crossed ligament or with chondromalacia patellae, by bringing the cleat forward [49, 50]. This is because, by varying the longitudinal position of the cleat, the lever arm of the lower limb is altered, changing its ranges of movement and muscular actions. Future research could be aimed at testing whether these variations in the position of the cleat yield the proposed results regarding the rehabilitation of lesions to the lower limb in the cyclist.

## CONCLUSION

The anterior-posterior ajustement of the cleat doesn´t depend of the shoe size or the metatarsal formula[36, 37], it is a constant. If we put the base of the cleat at 43% of the length of the cyclist´s shoe (measure since tip), we will have of the certain that the base of the cleat is at 3.6 cm of the head of the first metatarsal and this coincides with the pedal spindle. That positioning the base of the cleat at this distance favors the application of the vectors of the head of the first metatarsals on the pedal spindle. With the exact determination of the cleat position, proposed progressive rehabilitative treatments of lesions to the knee or ankle could be studied.

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FIGURE LEGENDS

FIGURE 1 and 2: Location of the metal element indicating the angulation

FIGURE 3: Cleat/I-metatarsal distance

FIGURE 4: Tip/cleat distance

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