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EFFECT OF THE TYPE OF FOOTWEAR ON BIOMECHANICAL PARAMETERS IN THE FOOT CONTACT PHASE IN MIDDLE-DISTANCE RUNNERS

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ABSTRACT

The aim of this study is to determine the effect of two types of running shoes: standard training shoes and racing shoes, on kinematic and kinetic parameters of the foot contact phase in middle-distance runners. Thirteen male athletes with an experience in national and international competition have participated. Data was collected using a force platform operating at 500 Hz, and three video cameras operating at 210 Hz. An electronic signal was used to synchronize the temporary registration systems. Participants passed through all experimental conditions, one of them using their racing shoes and the other using their standard training shoes. Runners were informed to place their dominant foot in the force platform, located on one of the lanes of the running track. Running speed was stablished at two levels: reduced and competition velocity, respectively. Results have demonstrated that wearing standard training shoes promote a heel strike pattern, whereas wearing racing shoes promote a midfoot strike and a greater angular displacement of the ankle joint. Data relating to horizontal component of the ground reaction forces allow us to state that at low running speeds, standard training shoes are more efficient than racing shoes.

Key Words: biomechanics, running, footwear, force platform, 2D photogrammetry

RESUMEN

El propósito de este estudio ha sido comprobar el efecto que tienen dos tipos de calzado: de competición y de entrenamiento, sobre los parámetros cinemáticos y cinéticos del apoyo del pie en corredores de medio fondo. Han participado 13 atletas varones, con una experiencia en competición nacional e internacional de más de cinco años. Para el registro de los datos, se ha utilizado una plataforma de fuerza, operando a 500 Hz y tres cámaras de vídeo, a 210 Hz. Una señal electrónica se utilizó para sincronizar temporalmente los sistemas de registro. Los atletas realizaron dos carreras lanzadas, una de ellas utilizando su calzado de competición habitual y la otra utilizando su calzado habitual de entrenamiento, debiendo apoyar el pie dominante sobre la plataforma de fuerza, situada en una de las calles de la pista de atletismo. La velocidad de carrera se bloqueó en dos niveles: reducida y de competición. Los resultados han puesto de manifiesto que el calzado de entrenamiento favorece el apoyo de retropié, mientras que el calzado de competición favorece el apoyo de mediopie y un mayor desplazamiento angular de la articulación del tobillo. Los datos relativos a las fuerzas horizontales nos permiten afirmar que, a velocidades reducidas, el calzado de entrenamiento es más eficiente que el calzado de competición.

Palabras clave: biomecánica, carrera, calzado, plataforma de fuerza, fotogrametría 2D

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INTRODUCTION

It is known that in the middle-distance athletic events, runners require an optimization of the energy demands related to physiological processes. However, performance of these athletes also depends on certain biomechanical factors related to running kinetics and kinematics. Some of these studies have focused on the biomechanical analysis of the foot contact phase, analyzing some differences in running technique, the effect of speed and type of footwear (De Wit et al., 2000; Divert et al., 2005; Lieberman et al., 2010). Regarding the type of footwear, has been demonstrated that it modifies some running kinetic and kinematic parameters (Nigg, 1986; Nigg et al., 1987). In this respect, it is known that in middle distance events runners usually use racing shoes, of which have different characteristics to those used during training sesions. These differences can be seen mainly in the rear of the shoe, as racing shoes do not have a cushioning system. Therefore, we believe the type of footwear could have some effect on individual running technique.

In order to reduce the risk of injury during long duration training sessions, runners usually use specific shoes with extra cushioning on the heel (Verdejo & Mills, 2004). Nigg & Segesser (1986) advocate the use of this shoe, considering that the heelpad should reduce loads, and therefore prevent the overload impacts arising at each foot strike. However, we consider that the excessive use of training shoes could have an effect on running technique. Thus, Mullen & Toby (2013) have shown that shoes with greater heel cushioning system facilitates a rearfoot placement in adolescent athletes. However, running barefoot or using racing shoes (without heelpad), promote a forefoot and midfoot placement. As stated above, the type of footwear could alter running biomechanics, since the initial contact of the foot (rearfoot, midfoot or forefoot) would have consequences on the use of the ankle joint as cushioning mechanism in the foot contact phase.

Lieberman et al. (2010) have investigated the contribution of the ankle joint as cushioning mechanism in foot contact phase, concluding that despite the hardness of the ground, barefoot runners produce less vertical peak force than runners who use shoes with heel cushioning system. This effect occurs due to an increased foot plantar flexion at touchdown, and a further coupling of the ankle joint during the impact, reducing the effect of inertia of the body. Divert et al. (2008) have shown that barefoot runners tend to make contact with the forefoot and midfoot point, reducing ground contact time, increasing the braking impulse of the center of mass (CM), and increasing the vertical leg stiffness. Furthermore, it has been found that in absence of heel cushioning systems, some changes occurs in the foot contact phase that reduces the vertical peak impact. This could be caused to prevent mechanical stress, which causes a neuro-mechanical adaptation that would improve the accumulation of elastic energy (De Wit et al., 2000; Divert et al., 2005).

A concept that has been linked to the running efficiency and the type of foot placement is the rate of leg stiffness during the stance phase. This index has been considered as the ratio between the maximum compression of the leg during the stance phase (Farley & Gonzalez, 1996). The contributions of Morin et al. (2007) suggest that the leg stiffness is directly related to the ground contact time and the running speed, being greater when running velocity increase and ground contact time is reduced. As stated above, as well as consideration of Divert et al. (2008), in the absence of heel cushioning system, leg stiffness could be increased, and thereby improved running efficiency.

As appears in the background described, during the course of this research is to test the effect of the type of footwear by rear cushion (cushioned training shoes and racing shoes) on kinematic and kinetic parameters in middle-distance runners. From the results of previous studies, cushioned heel shoes influence in running technique. So we consider as hypothesis that racing shoes, promote a forefoot and midfoot touchdown, facilitating a greater contribution of the ankle joint as a cushioning mechanism to reduce the vertical peak force at the moment of impact.

METHOD

Subjects

Thirteen male mid-distance runners with an experience of 5 years in national and international competition, have participated in our study (time in 1.000 meters= 156 ± 10 s; age= 22.8 ± 5.5 years; mass= 69.5 ± 5.3 kg; high= 1.80 ± 0.04 m). All subjects were informed and requested their consent to participate in this study following the guidelines of Ethics Committee of the University.

Material

We used a force platform 0.6 x 0.37 m, Dinascan/IBV, (Intitute of Biomechanics of Valencia, Valencia, Spain), operating at 500 Hz, which allowed us to record the horizontal and vertical components of the ground reaction forces exerted by the contact of the dominant foot (F_X y F_Z, respectively), and the horizontal component of the center of pressure (CP_X). A video camera (A), Casio EX – FH20, 210 Hz, recorded the sagittal plane of the athletes, from which the position and velocity of the CM before contacting the force platform was determined. A second camera (B) with the same characteristics, recorded at 210 Hz the sagittal planes of the lower limbs of the athletes focusing it vision in the foot contact phase. A third camera (C), with the same characteristics and frequencies, recorded the stance phase of the dominant foot about 50 meters from the force platform. An electronic signal was used to start recording of the force platform, plus a led on the active field of the cameras A and B allowing the temporary synchronization with the registration systems (the two cameras and the force platform).

Procedure

After a 15 minute warm-up, athletes received instructions to run twenty trials of 150 meters. Ten using their competition shoes (RS) and the other ten using their training shoes (TS). They had to place their dominant foot on the force platform, located in one of the runways of the track. Only got as valid those trials where the athletes placed their dominant foot in the force platform, with no apparent of speed and technique modification. To facilitate the foot placement on the force platform references were used on the track. In order to verify that the running pace remained constant during the stance phase, only were considered as valid those trails where the differences between the contact times did not exceed 6%. Trials were blocked in two running paces: a) competition velocity, considered the running pace at which they perform their best 1.000 meter in the track, and b) reduced velocity, considered the running pace at which they train their basic aerobic capacities (for this research was considered the 75% of their competition velocity).

Collection data

Following the methodology proposed by Gutiérrez-Dávila, Dapena & Campos (2006), the foot placement on the force platform was considered when the net vertical force component (F_Z) reached a value greater or equal to 1% of the body weight. The takeoff was considered when the vertical force component was less than 4 N. To evaluate the horizontal displacement of the center of pressure (CP_X), two horizontal distances were stablished: a) horizontal displacement of the CP, understood from the touch down trough takeoff *(CP displacement touchdown-takeoff);* and b) maximal displacement of the CP, considered as the maximum horizontal displacement covered by the CP *(Máx. CP Displacement)*. In Figure 1, are shown these two distances considered as the CP displacement.

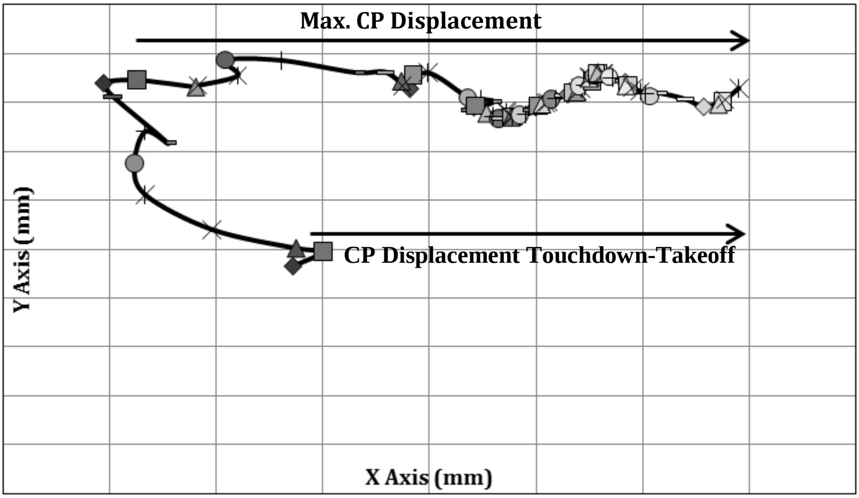

FIGURE 1: Plane coordinates of the center of pressure (CPX y CPY) during the stance phase. CP displacement Touchdown-Takeoff. Maximum displacement of the CP.

Using inverse dynamics, velocities and displacements of the center of mass (CM) during the stance phase were determined. To ensure this, the horizontal and vertical acceleration of the CM were calculated from the net ground reaction force (F_X y F_Z, respectively) and the mass of the subject. Next, the respective components of the CM velocity and displacement were determined through the integration of the acceleration-time and velocity-time function respectively, using the trapezoidal method for it with a time interval of 0.002 seconds. The integration constants were determined from video images (2D) from the A camera. To determine the position of the center of gravity (CG), model and inertial parameters proposed by Zatsiorsky & Seluyanov (1983) and adapted by de Leva (1996) was used. The calculation process began with the digitalization of the points that defined a model of sixteen consecutive images, where the foot placement on the force platform was between the seventh and the eighth image (range 1/120s). The plane coordinates were smoothed using a digital low-pass filter at 8 Hz (Winter, 1990). The calculation of velocity components, instantaneous velocity was used in the middle of this same time interval (seventh and eighth image), using the first derivative of the spline function of fifth grade of the respective components of the CG position of the subject.

Stance phase was divided into two time periods: a) *Time of braking impulse*, comprehended from touchdown through the horizontal ground reaction force gets positive, and b) *Time of acceleration impulse*, comprehended from which the horizontal ground reaction force gets positive through takeoff of the foot. In Figure 2, horizontal and vertical force components (F_X y F_Z, respectively) are shown, as well as the two periods in which the stance phase has been divided, for each runner analyzed.

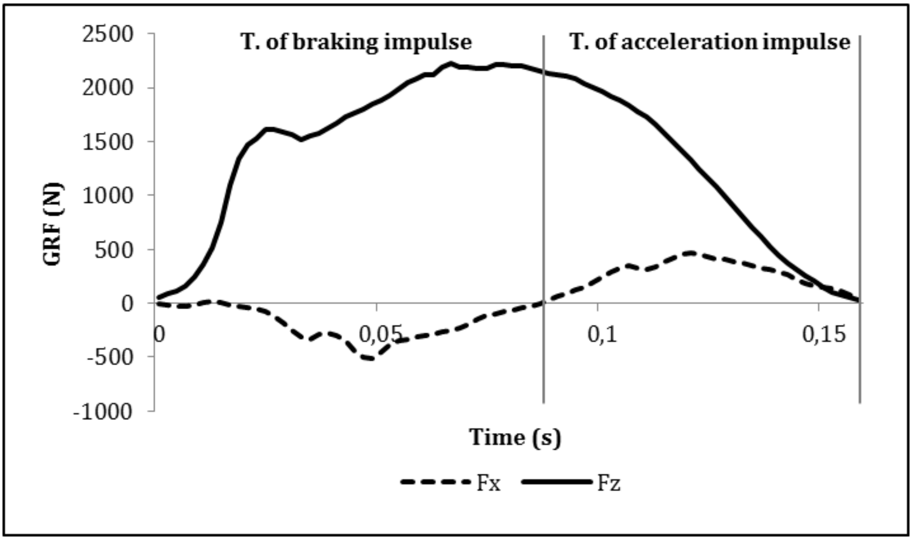

FIGURE 2: Horizontal and vertical components of the ground reaction forces exerted by the dominant leg during the stance phase.

To evaluate the horizontal distance between the CM and the CP in the stance phase, two criteria were considered: a) horizontal distance between the CM and the CP at touchdown *(Horizontal dist. CM-CP at touchdown)*, and b) horizontal distance comprehended between the CM and the midfoot at touchdown *(Horizontal dist. CM-Midfoot at touchdown)*. Midfoot was established as the distance between the toe and heel.

Images from the second camera (B), were used to calculate the angular displacements of the knee and ankle joints, from touchdown till the end breaking phase *($\theta_{(KNEE)}$ y $\theta_{(ANKLE)}$, respectively)*. For this, the photogrammetric analysis system Kinovea 0.8.15 was used. The knee joint angle was determined between the vectors defining the thigh (knee joint center – trochanter) and leg (knee joint center – ankle joint center). The ankle joint angle was determined from the vectors defining the leg and foot (ankle joint center – toe).

To calculate the leg stiffness during the stance phase, we have relied on the reference model described by Morin et al. (2007), but with some changes due to the possibility of incorporating the horizontal position of the CP. According to the model described, the leg stiffness (k_{leg}) was calculated from the following expressions:

$$k_{leg} = F_{max} \cdot \Delta L^{-1}$$

where F_{max} *is the maximal ground reaction force, expressed in kilonewtons (kN), while* ΔL *is compression distance of the supporting leg,*

The distance of leg compression (ΔL) was determined from the following expression:

$$\Delta L = L - \sqrt{L^2 - \left(\frac{vt_c - d}{2}\right)^2} + \Delta y_c$$

where L is the distance between the great trochanter and the CP at touchdown, v is the average velocity during the stance phase, tc is the ground contact time, d is the horizontal displacement of the CP during the stance phase, and 〖Δy〗_c is the maximal displacement of the CP during the stance phase.

RESULTS

In Table 1, numerical data of central tendency and differences between the means are shown. They are related to tests performed on reduced running velocity, in the two experimental conditions: racing shoes (RS) and training shoes (TS). According to the protocol used, the horizontal velocity of the CM at touchdown (V_X *touchdown)*, does not show any statistically significant differences. The same tendency is shown for vertical velocity of the CM at touchdown. There are significant differences found in the reduction of the horizontal velocity during the stance phase *(Reduction* V_X *in stance phase)*, being greater when running is performed with racing shoes ($p<0.05$).

TABLE 1
Descriptive and inferential statistics of the most significant variables, at reduced running velocities for the two experimental conditions (racing and training shoes, respectively).

Variables	RS	TS	F
Reduced velocity			
V_X touchdown (m/s)	5.61 ± 0.4	5.69± 0.4	Cond.
V_Z touchdown (m/s)	-0.91 ± 0.1	-0.92 ± 0.1	1.24
Reduction of V_X in stance phase (m/s)	-0.33 ± 0.07	-0.28 ± 0.06	8.75*
Ground contact time (s)	0.170 ± 0.022	0.168 ± 0.018	0.03
Time of braking impulse (s)	0.088 ± 0.013	0.087 ± 0.011	0.14
Time of acceleration impulse (s)	0.083 ± 0.012	0.081 ± 0.011	1.5
Horizontal dist. CM-CP at touchdown (m)	0.34 ± 0.05	0.31 ± 0.04	5.38*
Horizontal dist. CM-Midfoot at touchdown (m)	0.36 ± 0.08	0.36 ± 0.06	0.05
CP displacement touchdown-takeoff (m)	0.13 ± 0.07	0.17 ± 0.06	4.88*
Max. CP displacement (m)	0.16 ± 0.06	0.18 ± 0.06	1.98
$\theta_{(KNEE)}$ (º)	26 ± 5	31 ± 6	6.61*
$\theta_{(ANKLE)}$ (º)	26 ± 8	22 ± 7	2.77
Leg stiffness	22.2 ± 5.57	23.2 ± 4.76	2.50

With respect to temporary variables related to the stance phase (ground contact time, time of braking impulse, time of acceleration impulse), there were no statistically significant differences between the two experimental conditions. However, data clearly shows that in the horizontal distance between the center of mass (CM) and the center of pressure (CP) at touchdown *(Horizontal dist. CM-CP at touchdown)*, show some significant differences, being higher when racing shoes are used (0.34 vs. 0.31 m; $p<0.05$). By contrast, there were no significant differences in the horizontal distance between the CM and midfoot at touchdown *(Horizontal dist. CM-Midfoot at touchdown)*.

The horizontal displacement of the CP during the stance phase *(CP displacement touchdown-takeoff)*, shows some statistically significant differences ($p<0.05$), being higher when training shoes are used (0.13 vs. 0.17 m). This situation shows that when racing shows are used, the foot placement is more horizontal. However, the maximum displacement of the CP *(Max. CP Displacement)*, shows no differences between the means of the two experimental situations. This allow us to point out that when racing shoes are used, the CP tends to rearward a greater distance after the foot placement than when training shoes are used. There are same significant differences in the angular displacement of the knee joint *($\theta_{(KNEE)}$)*, being greater when using training shoes (26º vs. 31º; $p<0.05$). By contrast, there were no statistically significant differences in the angular displacement for the ankle joint *($\theta_{(ANKLE)}$)*.

Finally, Table 1 also presents the variable related to the leg stiffness during the stance phase *(Leg stiffness)*. Data shows that there are no differences between the means of the two experimental conditions.

In Table 2 are also shown the numerical data of central tendency and differences between the means, corresponding to the test carried out at competition velocity: using racing shoes (RS) and training shoes (TS). It is verified that the horizontal velocity of the CM at touchdown (*V_X touchdown)*, is similar for both type of footwear. In relation to the vertical velocity *(V_Z touchdown)*, no statistically significant differences are shown. In contrast to what indicate at low speeds, the reduction of the horizontal velocity of CM during the stance phase *(Reduction V_X in stance phase)*, did not show any statistically significant differences.

TABLE 2
Descriptive and inferential statistics of the most significant variables, at competition running velocities for the two experimental conditions (racing and training shoes, respectively).

Variables	**RS**	**TS**	**F**
Competition velocity			
V_X touchdown (m/s)	6.68 ± 0.51	6.78 ± 0.54	Cond.
V_Z touchdown (m/s)	-0.83 ± 0.15	-0.86 ± 0.22	0.17
Reduction of V_X in stance phase (m/s)	-0.30 ± 0.08	-0.31 ± 0.06	0.47
Ground contact time (s)	0.151 ± 0.020	0.153 ± 0.017	0.59
Time of braking impulse (s)	0.076 ± 0.011	0.081 ± 0.011	5.42*
Time of acceleration impulse (s)	0.075 ± 0.012	0.073 ± 0.010	3.43
Horizontal dist. CM-CP at touchdown (m)	0.35 ± 0.05	0.36 ± 0.04	0.16
Horizontal dist. CM-Midfoot at touchdown (m)	0.37 ± 0.07	0.38 ± 0.06	0.87
CP displacement touchdown-takeoff (m)	0.12 ± 0.05	0.17 ± 0.06	5.20*
Max. CP displacement (m)	0.17 ± 0.05	0.18 ± 0.06	1.19
$\theta_{(KNEE)}$ (º)	27 ± 6	26 ± 7	0.12
$\theta_{(ANKLE)}$ (º)	26 ± 11	22 ± 9	1.48
Leg stiffness	21.3 ± 5.2	21.7 ± 4.6	0.1

Just some significant differences were found in the time of braking impulse *(Time of braking phase)* with respect to temporary variables related to the stance phase, being higher when using training shoes (CE) (0.076 vs. 0.082 s; $p<0.05$). However, variables related to the horizontal distance between the CM and the foot *(Horizontal dist. CM-CP at touchdown, and Horizontal dist. CM-Midfoot at touchdown)* no significant differences are shown.

Data referred to the displacement of the CP, maintain a similar tendency as described in Table 1 for running trials al low velocities. Thus, some more differences were found between the means for the horizontal displacement of the CP during the stance phase *(CP displacement touchdown-takeoff, $p<0.05$)*, being higher when using training shoes (0.12 vs. 0.17 m). However, the maximum displacement of the CP *(Máx. CP Displacement)*, shows no differences between the means of the two experimental situations. There were no statistically significant differences between the angular displacements of the knee and ankle joints ($\theta_{(KNEE)}$ y $\theta_{(ANKLE)}$, respectively). Finally, in Table 2, also presents the variable related to the leg stiffness during the stance phase *(Leg stiffness)*. These results shows that there are no statistically significant differences for this variable.

DISCUSSION

We will begin by analyzing the results obtained at reduced running velocities. The most significant results for this running situation are related to the horizontal distance between the CM and the CP at touchdown *(Horizontal dist. CM-CP at touchdown)*, being higher when running shoes are used. The consequence of this is a greater reduction of the horizontal CM velocity during the braking impulse *(Reduction V_X in stance phase*, see Table 1*)*. Indeed, these results indicate that the reduction of the horizontal velocity during the stance phase is higher when racing shoes are used. Considering that there are no differences in the time used for braking impulse, this greater deceleration of the CM could be due to the increase of the horizontal ground reaction forces. From this point of view, racing footwear is less efficient than training footwear at low running velocities.

Another aspect that is revealed by analyzing the *"Horizontal dist. CM-CP at touchdown"*, is the evidence that athletes tend make a midfoot placement whit racing shoes, whereas training shoes promote to contact with rearfoot. This statement is made because there were no significant differences in the variable related to the horizontal distance between the CM and the midfoot *(Horizontal dist. CM-Midfoot at touchdown)*. Indeed, data indicates that when this distance is expressed relative to the midpoint of the foot, the mean is similar for both type of footwear. However, when expressed with respect to the CP, there are some significant differences between means, indicating that the CP is nearer to the rearfoot when training shoes are used (0.02 vs 0.05 m, racing and training shoes, respectively). In Figure 3, are graphically represented these distances and the position of the CP for both type of footwear. These results reaffirm the contributions described by De Wit et al. (2000) which shows that in the absence of heel cushioning (barefoot runners), there is the need to perform a forefoot placement, to avoid the ground impacts of the heel.

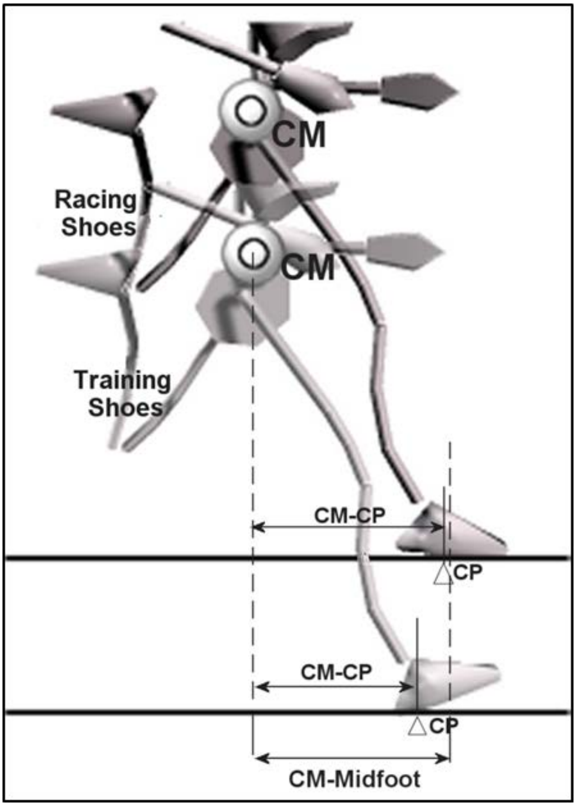

FIGURE 3: Graphic representation of the "Horizontal dist. CM-CP at touchdown" and "Horizontal dist. CM-Midfoot at touchdown" variables for the two types of footwear (racing and training shoes)

Also, these results suggest that the use of racing shoes reduces the horizontal displacement of the center of pressure (CP), from touchdown through takeoff *(CP displacement touchdown-takeoff)*. However, the maximum CP displacement *(Max. CP displacement)* is similar for both types of footwear (see Table 1 and Figure 1). These facts indicate that after making contact with the ground, the CP tend to move back with the two types of shoes, but this movement is grater when using racing shoes (0.03 vs 0.01 m, racing and training shoes, respectively). The CP rearward displacement during the braking impulse confirms that racing footwear facilitate a midfoot touchdown. Mullen & Toby (2013) refer to this fact by showing that training shows promotes rearfoot touchdown, while racing shoes promotes forefoot touchdown.

Another aspect to consider when analyzing results related to the horizontal displacement of the CP, is that, it allows us to justify that there are no significant differences in the *Time of braking impulse* (see Table 1). So when using racing shoes, after touchdown, the CP stars to move backwards, while the CM moves forward. This mechanism reduces the time that CM need to reach the CP horizontally, although the horizontal distance between the CM and CP at touchdown *(Horizontal dist. CM-CP at touchdown)* is higher when racing shoes are used. Thus, racing shoes facilitates cushioning mechanisms explained by Lieberman et al. (2010), were barefoot runners have a greater contribution of the ankle joint during the stance phase, producing a greater plantar flexion at touchdown, and a higher coupling of the ankle joint during ground impact.

Surprisingly, the leg stiffness coefficient during the stance phase *(Leg stiffness)*, was similar for both type of footwear. Having stated that racing shoes promote midfoot touchdown, we might think that there would be a greater cushioning due to the action of the ankle joint. Indeed, there is a greater angular displacement of the ankle joint when racing shoes are used, although there are no statistically significant differences ($\theta_{(ANKLE)}$, see Table 1). However, the angular displacement of the knee joint during the braking impulse ($\theta_{(KNEE)}$), was significantly greater when training shoes were used. Although the leg stiffness was similar for both type of footwear, the cushioning mechanism is different. Thus, when training shoes are used, cushioning is primarily based on the impact absorption system of the shoe itself, with an increased keen flexion. When racing shoes are used, cushioning is based on a higher ankle joint action and a lower knee flexion.

These results are contradictory to those proposed by Morin et al. (2007), which shows that the type of foot placement during running influences significantly to the leg stiffness. These discrepancies could be related to changes made to calculate the leg stiffness in this study. First, in the calculation proposed by Morin et al. (2007), the initial leg length (L) was assumed as the distance that defines the great trochanter and the ground contact point in standing position. However, in this study has been considered as the distance between the great trochanter and the CP at touchdown. Secondly, Morin et al. (2007) did not consider the real CP displacement of each subject, instead, to avoid the loss of accuracy in the calculation they used a standard displacement, proposed by Lee & Farley (1998) (d=0.157 ± 0.006 m for running pace between 1.5 m/s y 5.0 m/s).

Then, we will analyze the results obtained for competition velocity. As seen in Table 2, differences between both type of footwear have been less than running at reduced velocities, probably due to a shorter ground contact time. In relation to the results obtained, the only temporal variable that shows some significantly differences was *"Time of braking impulse"*, which is lower when racing shoes are used (0.076 vs 0.081 s, racing and training shoes, respectively). The explanation for this is a quicker horizontal approach between the CM and the CP during the stance phase. In contrast to what happened at low velocities, runners tends to contact with the midfoot point, regardless of the footwear they use. Indeed, results confirm this trend, there are no significant differences for both variables: *"Horizontal dist. CM-CP at touchdown"* and *"Horizontal dist. CM-Midfoot at touchdown"*. This fact indicates that the horizontal distance between the CM and the CP at tocuhdown is similar for both type of footwear. Data also suggest that, the time of braking impulse *(Time of braking impulse)* is lower when racing shoes are used. This could be explained because there are some significant differences in the CP displacement during the stance phase. In this sense, data indicates that when racing shoes are used, the CP has a greater rearward (0.05 vs 0.01 m, racing and training shoes, respectively). The best explanation for this could be based on the ankle joint action during the foot contact phase. Although there are no statistically significant differences in the angular displacement of the ankle joint ($\theta_{(ANKLE)}$), we believe that as what occurs at reduced velocities, the cushioning mechanism is based on the ankle joint, when using racing shoes. However, when using training shoes, this mechanism is based on the heel impact absorption system of the shoes itself. We consider that future research should empirically test this hypothesis.

CONCLUSIONS

It is confirmed that, at low running velocities, racing shoes facilitate midfoot touchdown, while training shoes would favor a rearfoot touchdown. Thus, the contribution of the ankle joint as cushioning mechanism is increased when using a racing footwear.

When racing shoes are used, horizontal ground reaction forces increase during the braking impulse. These results in a greater reduction of the horizontal velocity of the CM. In this sense, data shows that at low running velocities, training shoes are more efficient than racing shoes.

At competition velocities touchdown is similar for the two types of footwear, however, the time of braking impulse decreases when using racing shoes. Therefore, we might suggest that racing shoes could be more efficient and could also favor a greater participation of the ankle joint at competition velocities. Although we should be cautious with this statement. Future research of the foot contact phase in competition running, using 3D photogrammetry at higher recording frequencies would allow us to test this hypothesis.

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