García-Arroyo, J.; Pacheco-da-Costa, S.; Molina-Rueda, F. y Alguacil-Diego, I.M. (202x) Analysis of Plantar Pressure during the Running in Place over Different Surfaces. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. (*) pp. *. Http://cdeporte.rediris.es/revista/___*

ORIGINAL

ANALYSIS OF PLANTAR PRESSURE DURING RUNNING IN PLACE OVER DIFFERENT SURFACES

ANÁLISIS DE LA PRESIÓN PLANTAR DURANTE LA CARRERA EN EL SITIO EN DIFERENTES SUPERFICIES

PENDIENTE DE PUBLICACIÓN / IN PRESS

García-Arroyo, J.[1]; Pacheco-da-Costa, S.[2]; Molina-Rueda, F.[3]; Alguacil-Diego, I.M.[3]

[1] Fisioterapeuta. Centro Ten (España) jaimegarroyo@gmail.com

[2] PhD.Departamento de Enfermería y Fisioterapia. Universidad de Alcalá (España) soraya.pacheco@uah.es

[3] PhD. Departamento de Fisioterapia, Terapia Ocupacionial, Rehabilitación y Medicina Física. Facultad de Ciencias de la Salud. Universidad Rey Juan Carlos (España) francisco.molina@urjc.es, isabel.alguacil@urjc.es

Spanish-English translator: Isabel Quintero, info@iqtraduccion.com, revisada por Proof-Reading-Service

Código UNESCO / UNESCO code: 321311 Fisioterapia / Physiotherapy
Clasificación Consejo de Europa / Council of Europe classification: 14. Fisioterapia y rehabilitación / Physiotherapy and rehabilitation

Recibido 12 de junio de 2020 **Received** June 12, 2020
Aceptado 1 de noviembre de 2020 **Accepted** November 1, 2020

ABSTRACT

The aim of this study is to evaluate in 36 amateur runners the Maximum Force and Peak Pressure of the foot on three surfaces commonly used for running in place training (artificial turf, rubber floor and flat trampoline). The values of force and pressure were recorded by means of instrumented insoles (Gebiomized®, Munster, Germany). The following parameters were obtained: Maximum Force (N) and Peak Pressure (N/cm^2) in 6 specific areas of the foot.

According to the results, the maximum force exerted by the dominant foot on artificial grass (657 N) and rubber floor (692.5 N) was significantly higher than that recorded on the trampoline (262 N). Regarding the pressure, most of the pressure exerted by the foot on hard surfaces (artificial grass and technical floor), was observed in the heads of the metatarsals, while on the trampoline the pressure was distributed between the latter and the calcaneus.

KEYWORDS: Biomechanics; Running; Insole; Plantar pressure; Compressive forces.

RESUMEN

El objetivo de este trabajo es evaluar en 36 corredores aficionados, la fuerza y las presiones del pie sobre tres superficies comúnmente empleadas para el entrenamiento de la carrera en el sitio (césped artificial, suelo técnico de caucho y trampolín plano). Los valores de fuerza y presión se registraron mediante plantillas instrumentadas **(**Gebiomized® Munster, Germany). Se obtuvieron los siguientes parámetros: Fuerza máxima (N) y picos de presión (N/cm$^{2)}$ en 6 zonas específicas del pie.

Según los resultados, la fuerza máxima ejercida por el pie dominante en césped artificial (657 N) y en suelo técnico de caucho (692,5 N) fue significativamente superior al registrado sobre el trampolín (262 N). Respecto a la presión, la mayor parte de la presión ejercida por el pie en superficies duras (césped artificial y suelo técnico de caucho), se observó en las cabezas de los metatarsianos, mientras que en el trampolín la presión se repartió entre estas y el calcáneo.

PALABRAS CLAVE: Biomecánica, Carrera; Plantillas; Presión plantar; Fuerzas de compresión.

PENDIENTE DE PUBLICACIÓN / IN PRESS

INTRODUCTION

Running is an extremely popular sport, attracting a growing number of amateur runners each year. According to data from the year 2013, in the USA alone, almost 30 million people ran for more than 50 days (Runningusa.org, 2013). In Spain, the percentage of the population who practices running at least once a month equals 14.5%, making it the second-most popular sport after cycling (17%) (Educacionyfp.gob.es, 2020).

Running is an activity that is present in most sports, and for this reason it is commonly included as a part of athletes' recovery periods. To practice running correctly, and to minimise the risk of injury, some requirements must be met. These include maintaining a correct postural alignment and having appropriate muscle strength and preserved joint ranges. (Brigaud & Villena, 2016; Goss & Gross, 2011).

In studies of the transition towards running, a series of training strategies have been described, such as: decreasing velocity (Pires, Lay, & Rubenson, 2014), reducing the athlete's weight via partial immersion in water (Ruschel, Haupenthal, Hubert, de Brito Fontana, & Roesler, 2010), running in deep water (Bushman et al., 1997), the use of treadmills with positive pressure (Neal, Fleming, Eberman, Games, & Vaughan, 2016), alternating running with walking (Keijsers, Stolwijk, & Pataky, 2010), shortening stride length (Pires et al., 2014) or varying the tilt of the running surface (Van Caekenberghe, De Smet, Segers,

& De Clercq, 2010). In this connection, to propose methods of avoiding overload during recovery periods and preventing possible injuries, several authors have analysed plantar pressure upon different surfaces (Hong et al., 2012; Tessutti et al., 2012; El Kati et al., 2010; Stolwijk et al., 2010; Page, 2013). These analyses would enable athletes to appropriately grade training sessions by controlling the pressure generated by the foot upon different contact surfaces, as well as providing information about the hardness of the surfaces employed and the areas of the sole of the foot that receive more, or less, pressure, which in turn would enable the selection of the most ideal surface for training.

Compared with pressure platforms, insole systems which are integrated into shoes, such as those used in our study, have the advantage of being more flexible, mobile and simple to use, as well as offering increased adaptability to various types of shoes of different materials, characteristics and heel heights (drop). Furthermore, the subject can practice running with a more natural gesture, as the support area does not have to coincide with the center of the platform (Zulkifli & Loh, 2018).

However, since running in place is a common training modality, knowledge about the pressures exerted on the foot in different surfaces is limited.
The aim of the present study was to assess and compare the plantar force and pressures in athletes upon the following commonly used surfaces for running in place training: artificial grass, technical floor and a flat trampoline. The examination of the variations of plantar force and plantar pressure on different surfaces may facilitate a more appropriate grading of training and be helpful for selecting the most suitable surface for each stage of recovery after an injury.

METHODS

Subjects

The recruitment of participants was carried out by placing notices on several notice boards at municipal sports centers, as well as at the training center where the tests were performed. The following inclusion criteria were established: individuals aged between 25 and 55 years, recreational runners, and those who were accustomed to running and who exercised at least three hours per week.
The exclusion criteria were that the participants could not have flat feet, sensitivity disorders, use corrective insoles, have less than 25° of ankle dorsiflexion or have sustained an injury to the lower limbs in the six months prior to the performance of the study.

Ethical aspects

All participants signed an informed consent form. Prior to the performance of the study, the local Ethics Committee granted approval for the study with the register number: 0304201707817. The procedures employed during the present study have fulfilled the ethical principles for medical research on human beings

PENDIENTE DE PUBLICACIÓN / IN PRESS

gathered in the Helsinki Declaration (The World Medical Association, Wma.net. 2019).

Procedure

This study took place at a sports center in Madrid (Spain), between June 2018 and September 2018.

During the recruitment session, the participants were interviewed with the aim of determining they fulfilled the inclusion criteria. The participants were asked not to train for more than 45 minutes on the day of the test, and not to compete on the previous day. Furthermore, if any participant felt pain during the performance of any of the tests, the activity was interrupted.

The intensity of the physical activity was quantified using the *International Physical Activity Questionnaire* (IPAQ) (Skelton, 2000). The absence of flat feet was measured using the *navicular drop test* (Rajakaruna, Arulsingh, Raj, & Sinha, 2015). Ankle dorsiflexion was assessed using the ankle dorsiflexion test (Langarika-Rocafort, Emparanza, Aramendi, Castellano, & Calleja-González, 2017) with the digital inclinometer of the smartphone application Goniometer Pro 5FUF5 CO®, considered to be valid and reliable (Kuegler et al. in 2015; Pourahmadi et al. in 2016).

Prior to the performance of the tests, data from each participant (weight, height, age and dominant leg) were collected using the step forward test (Velotta, Weyer, Ramirez, Winstead, & Bahamonde, 2011).

During the tests, the individual was asked to run in place on three surfaces: 1) artificial grass with Fifa® Quality Pro certification; 2) technical rubber flooring commonly employed on sports surfaces; and 3) a flat trampoline by Gymnova®. The participants were asked to perform a warm-up session based on the following sequence: 1) four minutes of soft static bicycle pedaling on a static WattBike® (Nottingham, UK) bicycle at 80 rpm and with a power of 90-100 W without exceeding 100 W.; 2) two minutes of light jogging on an artificial grass surface and exercises for hip, knee and ankle mobility (hurdles, leg opening exercises, flexion and extension stretches and lunge movements). In addition, each participant could perform a small 30-seconds trial to become more accustomed to the test. Between each test, a one-minute rest period was established, and the order of performance of the tests on the surfaces was randomised (Graphpad®). All tests were performed indoors, between 5pm and 7pm and in the same environmental temperature (22-23°C) and humidity (55-60%) conditions.

To define the speed of execution, a metronome was used (Lima Alberton et al., 2015) the Real Metronome Pro® (Gismart Limited, UK) mobile application. A cadence of 180 rpm was established, so the cadence of each leg was 90 impacts per minute (Figure 1).

PENDIENTE DE PUBLICACIÓN / IN PRESS

Figure 1

Subject on artificial grass, technical rubber flooring and flat trampoline.

Instruments

Gebiomized® (Munster, Germany) plantar pressure insoles were used. These insoles are equipped with 40-64 sensors per unit, depending on the size of the foot, registering a maximum frequency of 200 Hz and presenting a resolution of 12 bits (Nogueras Miranda, Grande Rodríguez, & Cordente Martínez, 2018). The size of the insoles used in the study varied between 245 mm (39 European size) to 295 mm (44.5 European size). The instrumental insoles were placed inside the training shoes (Adidas® Supernova Glide 6 model, with an 11 mm drop and a weight of 295 g for shoe size 42) (Stöggl & Martiner, 2016). The insoles were connected using a transmitter device attached to the individual's back.

Outcome measures

The outcome measures were quantified using the software designed for the instrumental insoles. The insoles registered data from 50 sensor points and the software then calculated the virtual pressure values between points, where no sensors were placed. There was a produced a uniform display distribution. Once the appropriate speed was reached on each test, 10 steps were registered with each foot, beginning with the left foot. Based on these 10 steps and on graphic virtual assessment, the most correct and symmetrical six consecutive steps were selected (Hong, Wang, Li, & Zhou, 2012).

The study variables gathered were:

- Maximum strength (Fmax) on the whole sole of the foot (N). This is defined as a vectorial magnitude which is measured when applying an acceleration of 1m/s² to a body of 1 kg of mass. Knowing the area of each sensor, the total force value that the foot receives can be calculated for the duration that the stimulus lasts.

- Peak pressure (N/cm2), was defined as the pressure of the force applied in a perpendicular direction per surface unit. In this case, six areas were studied: zone 1 (PP1, toes), zone 2 (PP2, head of the first metatarsal bone), zone 3 (PP3, 2nd, 3rd and 4th metatarsal bones), zone 4 (PP4,

PENDIENTE DE PUBLICACIÓN / IN PRESS

head of the 5th metatarsal bone), zone 5 (PP5, longitudinal arch of the foot) and zone 6 (PP6, calcaneus).

Statistical analysis

The statistical analysis was performed using the IBM SPSS statistics® program (version 22.0). The results of the study variables were expressed using the median and interquartile range. To determine whether the data followed a normal distribution, the Shapiro-Wilk test was used. As a normal distribution was not observed, the Friedman test for repeated measures was used. For the variables where significant differences were obtained, a Wilcoxon signed-rank test was used, which enabled the comparison of two related samples. As three comparisons were performed in the study (artificial grass vs. technical rubber floor, artificial grass vs. trampoline, technical rubber floor vs. trampoline) a value of $p<.016$ was considered a level of statistical significance (after applying the Bonferroni correction Bonferroni: $\alpha = .05/3$).

RESULTS

Figure 2 displays a flow diagram of the study participants. Of the 40 initially eligible subjects, 36 completed the study (age 33.9 ± 7.2 years; weight 75.3 ± 7.8 kg; height 179.0 ± 7.5 cm). Except for three subjects, the remainder presented a right dominance for the lower limb. All participants were in Category 2 (moderately active) of the IPAQ.

The registers of total pressure and areas 1, 2, 3, 4 and 5 of the foot (Table 1) showed similar findings, and the Fmax values obtained, from greater to lesser, were those registered on rubber technical flooring (692.5 N), artificial grass (657 N) and the trampoline (262 N) (floor vs. grass vs. trampoline: $p<0.01$). The pairwise comparison also reflected significant differences, observing a more distributed pressure, as expected, on the deformable trampoline surface.

PENDIENTE DE PUBLICACIÓN / IN PRESS

Table 1. Median and interquartile range of the pressure variables on the different surfaces

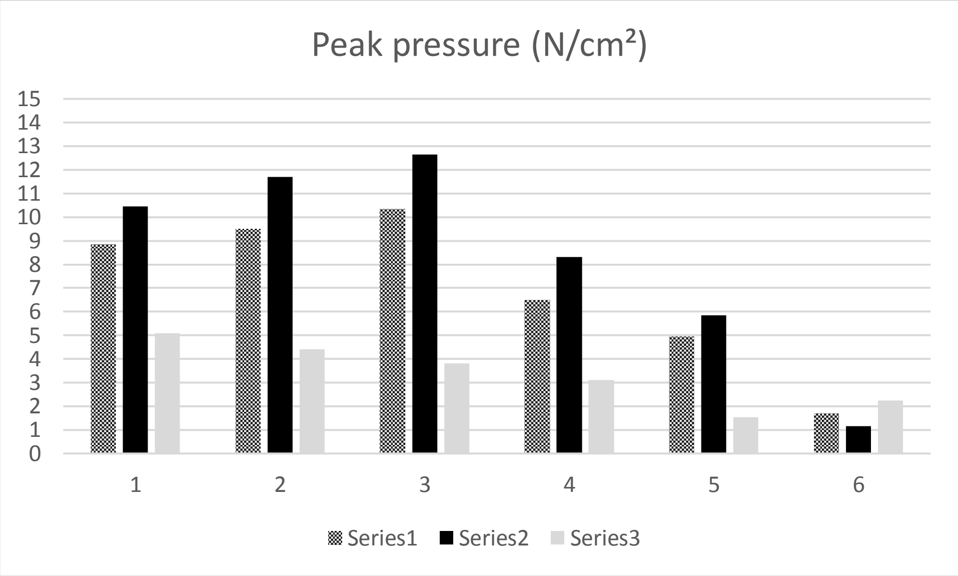
	Artificial grass		Rubber technical floor		Trampoline		Friedman		Wilcoxon	
	Median	**RI**	**Median**	**RI**	**Median**	**RI**	**Chi**	**P**	**Z**	**p**
Fmax (N)	657	398	692.5	377	216	165	36.38	p<0.01	a) 4.321 b)-5.232 c)-5.232	a) p<0.01 b) p<0.01 c) p<0.01
PP1 (N/cm²)	8.85	5.6	10.45	6	5.1	6.3	17.08	p<0.01	a) 1.303 b)-4.086 c)-4.235	a) 0.193 b) p<0.01 c) p<0.01
PP2 (N/cm²)	9.5	9.5	11.7	10.9	4.4	6.8	56.84	p<0.01	a) 3.89 b)-5.193 c)-5.232	a) p<0.01 b) p<0.01 c) p<0.01
PP3 (N/cm²)	10.35	4.9	12.65	5.9	3.8	3.3	64.88	p<0.01	a) 4.769 b)-5.232 c)-5.232	a) p<0.01 b) p<0.01 c) p<0.01
PP4 (N/cm²)	6.5	3.4	8.3	5.3	3.1	1.5	62.36	p<0.01	a) 4.128 b)-5.201 c)-5.233	a) p<0.01 b) p<0.01 c) p<0.01
PP5 (N/cm²)	4.95	3.8	5.85	3.7	1.55	2	58.42	p<0.01	a) 2.785 b)-5.232 c)-5.232	a) 0.005 b) p<0.01 c) p<0.01
PP6 (N/cm²)	1.7	3.3	1.15	3.4	2.25	1.6	3.95	0.138	a)-1.865 b) 0.024 c)-1.712	a) 0.062 b) 0.981 c) 0.087

a) Artificial grass vs. floor; b) artificial grass vs. trampoline; c) floor vs. trampoline. Fmax: Maximum force (in the entire foot region), PP1: peak pressure in area 1 (front of foot), PP2: peak pressure in area 2 (head of the first metatarsal), PP3: peak pressure in area 3 (heads of the 2nd, 3rd and 4th metatarsal bones), PP4: peak pressure in area 4 (head of 5th metatarsal), PP5: Peak pressure in area 5 (longitudinal arch of the foot), PP6: peak pressure in area 6 (calcaneal bone).

On the harder surfaces (artificial grass and technical rubber floor), the pressure applied was greater upon the anterior foot region (zones 1, 2 and 3). However, the pressure registers of area PP5 did not follow the described tendency. The higher values were registered on the trampoline (2.25 N/cm²), followed by artificial grass (1.7 N/cm²) and rubber flooring (1.15 N/cm²), although these differences were not significant (Figure 2).

PENDIENTE DE PUBLICACIÓN / IN PRESS

Figure 3. Peak pressure per area on the three surfaces.



Units of peak plantar pressure are expressed in N/cm². PP1: peak pressure in area 1 (front of foot), PP2: peak pressure in area 2 (head of the metatarsal), PP1+2: sum of the peak pressures in areas 1 and 2, PP3: peak pressure in area 3 (heads of the 2nd, 3rd and 4th metatarsal), PP4: peak pressure in area 4 (head of 5th metatarsal), PP5: Peak pressure in area 5 (longitudinal arch of the foot), PP6: peak pressure in area 6 (calcaneus bone).

Considering the percentage of pressure exerted with respect to the maximum value of each surface (Table 2), we observe that, all the areas of highest pressure are located in the anteromedial part of the foot (areas 1, 2 and 3); however, on a deformable surface such as the trampoline, the record obtained in the back of the foot stands out, as it is higher than the pressure obtained on the hardest surfaces.

Table 2. Comparison of Peak pressure in the foot areas

	Surface		
Area	Artificial Turf	Rubber technical floor	Trampoline
1	86	83	100
2	92	92	86
3	100	100	75
4	63	66	61
5	48	46	30
6	16	9	44

Percentage of Peak pressure with respect to the maximum area that marks the maximum peak (area 3 on artificial grass and rubber technical floor and area 1 on trampoline)

DISCUSSION

The aim of this study was to examine the values of plantar force and pressure for each of the areas of the foot when running in place on different surfaces (artificial grass, technical flooring and a flat trampoline). The study findings may be useful for rehabilitation purposes and for the return to sports post injury, as running in place is a commonly used recovery activity in most sports (Sáez de

PENDIENTE DE PUBLICACIÓN / IN PRESS

Villareal, Suárez-Arrones, Requena, Haff, & Ferret, 2015). Therefore, understanding the level of impact that the foot undergoes may enable the selection of a more ideal surface.

According to the findings of this study, running in place on artificial grass and technical rubber flooring is associated with higher values of pressure exercised by the foot compared with running in place on a flat trampoline. As expected, while running on the former hard surfaces, the anterior foot regions generate greater pressures and the technique used by the individual adapts to the contact surface. This observation is based on the 'spring mass' model described by Blickhan in 1989 in Grimmer et al., 2008, according to which lower limb tension is adjusted depending on the surface (Grimmer, Ernst, Gunther, & Blickhan, 2008).

Our results coincide with those observed by other authors (Tessutti et al., 2012; Wang, Hong, Li, & Zhou, 2012). Thus, a study by Tessutti et al. in 2010 analysed plantar pressure during linear running on four surfaces (asphalt, cement, rubber and natural grass) and found that reduced pressures were found when running on soft rather than hard surfaces. Also, the pressure was predominantly located on the anterior and medial part of the foot when running on cement and asphalt. The posterior part of the foot is the one that receives the least pressure.

The type of surface used in running has been associated with the injury etiology of the lower limb. Therefore, certain surfaces are more appropriate than others for treating or preventing specific injuries. Thus, running on artificial grass would decrease the plantar pressure in recreational runners, and could reduce the total stress on the musculoskeletal system when compared with other runners who train on more rigid surfaces.

Nonetheless, independent of the characteristics of the possible injury, there is a consensus in the literature that one of the strategies for treating an injury to the lower limb is to decrease the load supported by the foot (Bertelsen et al., 2017) which, in our case, would mean using the trampoline as the optimal training surface. During the functional stage of rehabilitation after bone injuries caused by stress of the lower limb, Dugan and Weber (2007) recommend prioritising a reduced pressure on the area or, at least, minimising the same, using deformable surfaces such as the mini-trampoline. These surfaces reduce the demand on the proprioceptive system and enable athletes to focus on and maximise the strength of the running gesture, which may have deteriorated with lower limb injuries (Paredes Hernández, Martos Varela, & Romero Moraleda, 2011; Romero-Franco, Martínez-Amat, & Martínez-López, 2013).

The data revealed by our study indicate that deformable surfaces, such as the flat trampoline, may reduce peak pressure upon all the areas of the foot. The risk of injury is reportedly greater when runners are subject to high impact forces (Lopes, Hespanhol, Yeung, & Costa, 2012), and soft surfaces can reduce this risk (Molloy, 2016). Therefore, runners who acquire the habit of reducing the impact forces against the floor minimise the effect of these forces on the body and present a lower risk of developing injuries (Hreljac, 2004).

PENDIENTE DE PUBLICACIÓN / IN PRESS

Consequently, it seems logical to consider that the trampoline is the training tool of choice in the recovery of runners who have suffered an injury to the lower limb.

The scientific literature to date focuses on the study of different running surfaces as potencial causes of injury, rather than on the analysis of the ideal surface for sports rehabilitation periods (Hong et al., 2012; Tessutti et al., 2012; Tessutti, Trombini-Souza, Ribeiro, Nunes, Sacco, 2008). We suggest that the first choice should be a deformable surface such as a flat trampoline. Of the commonly described injuries related to the surface on which athletes exercise, osteoarticular pathologies are particularly highlighted, such as meniscus injuries, tibial stress syndrome, stress fractures and injuries to the vertebral column (Taunton, 2002). Therefore, for running rehabilitation after this type of injury, the use of soft surfaces such as the trampoline should be recommended. In addition, in case of forefoot injuries (metatarsalgia and stress fractures) (Liem, Truswell, & Harrast, 2013) it would be advisable to avoid the use of hard surfaces in the initial phases of training, since, as evidenced in the present work, the greatest magnitude of pressure when running on hard surfaces such as raised rubber floors or grass occurs in the forefoot areas.

However, soft surfaces may not be appropriate for running rehabilitation in patients with rearfoot pathology such as plantar fasciitis.
When running, the plantar fascia participates in the absorption of body weight, specifically in the first part of the loading phase, and the rearfoot is the area with a higher peak pressure (Lopes et al., 2012). This study suggest that, in rear foot injuries, the trampoline is not the most appropriate surface.

Study limitations

This study presents several limitations. The small sample size limits interpretation of results. Only males were included, so the findings cannot be extrapolated to the female population. Finally, we would recommend performing a running in place analysis using other commonly used surfaces such as natural grass and pavement.

Conclusions

Maximum force and the peak plantar pressure values vary according to the surface used when running in place. Hard surfaces, such as artificial grass and rubber technical floor, generate greater pressures in the foot, especially in the front area, when running in place, compared with deformable surfaces, such as the trampoline

REFERENCES

Bertelsen, M. L., Hulme, A., Petersen, J., Brund, R. K., Sørensen, H., Finch, C. F., & Nielsen, R. (2017). A framework for the etiology of running-related injuries. *Scandinavian Journal of Medicine and Science in Sports, 27*(11), 1170–1180. doi: 10.1111/sms.12883

PENDIENTE DE PUBLICACIÓN / IN PRESS

Brigaud, F. (2016). *La carrera. Postura, Biomecánica y Rendimiento*. Ed. Paidotriobo. Barcelona.

Bushman, B. A., Flynn, M. G., & Andres, F. F. (1997). Effect of 4 weeks of deep water run training on performance. *Medicine and Science in Sports and Exercise, 29*(5):694–699.

Running USA. Cdn.trustedpartner.com. 2019 [accessed 12 March 2019]. Retrieved from:
http://cdn.trustedpartner.com/docs/library/RunningUSA2012/RunningUSA_NRS_2017.pdf

Dugan, S. A., & Weber, K. M. (2007). Stress Fractures and Rehabilitation. *Physical Medicine and Rehabilitation Clinics of North America, 18*(3), 401–416. doi: 10.1016/j.pmr.2007.04.003

Educacionyfp.gob.es (2019). [Accessed 12 March 2019]. Available at: http://www.educacionyfp.gob.es/servicios-al-ciudadano-mecd/dms/mecd/servicios-al-ciudadano-mecd/estadisticas/deporte/anuario-deporte/AED-2017/Anuario_de_Estadisticas_Deportivas_2017.pdf

El Kati, R., Forrester, S., & Fleming, P. (2010). Evaluation of pressure insoles during running. *Procedia Engineering, 2*(2), 3053–3058.

Grimmer, S., Ernst, M., Gunther, M., & Blickhan, R. (2008). Running on uneven ground: leg adjustment to vertical steps and self-stability. *Journal of Experimental Biology, 211*(18), 2989–3000. doi: 10.1242/jeb.014357

Goss, D. L., & Gross, M. T. (2012). A review of mechanics and injury trends among various running styles. *U.S. Army Medical Department Journal*, Jul-Sep, 62–71.

Hong, Y., Wang, L., Li, J. X., & Zhou, J. H. (2012). Comparison of plantar loads during treadmill and overground running. *Journal of Science and Medicine in Sports, 15*(6), 554–560.

Hreljac, A. (2004). Impact and Overuse Injuries in Runners. *Medicine and Science in Sports and Exercise, 36*(5), 845–849. doi: 10.1249/01.MSS.0000126803.66636.DD

Keijsers, N. L. W., Stolwijk, N. M., & Pataky, T. C. (2010). Linear dependence of peak, mean, and pressure-time integral values in plantar pressure images. *Gait and Posture, 31*(1), 140–142.

Kuegler, P., Wurzer, P., Tuca, A., Sendlhofer, G., Lumenta, D. B., Giretzlehner, M., et al. (2015). Goniometer-apps in hand surgery and their applicability in daily clinical practice. *Safety in Health, 1*, 11

Langarika-Rocafort, A., Emparanza, J. I., Aramendi, J. F., Castellano, J., & Calleja-González, J. (2017). Intra-rater reliability and agreement of various methods of measurement to assess dorsiflexion in the Weight Bearing Dorsiflexion Lunge Test (WBLT) among female athletes. *Physical Therapy in Sports, 23*, 37–44.

Liem, B., Truswell, H., & Harrast, M. (2013). Rehabilitation and Return to Running After Lower Limb Stress Fractures. *Current Sports Medicine Reports, 12*(3): 200–207.

Lima Alberton, C., Santana Pinto, S., Silva Azenha, N., Cadore, E., Peikriszwili Tartaruga M., Brasil, B., et al. (2015). Kinesiological Analysis of Stationary Running Performed in Aquatic and Dry Land Environments. *Journal of Human Kinetics, 49*: 514.

PENDIENTE DE PUBLICACIÓN / IN PRESS

Lopes, A. D., Hespanhol, L. C., Yeung, S. S., & Pena Costa, L. O. (2012). What are the Main Running Related Musculoskeletal Injuries?. *Sports Medicine, 42*(10), 892–905. doi: 10.2165/11631170-000000000-00000

Molloy, J. M. (2016). Factors Influencing Running-Related Musculoskeletal Injury Risk Among U.S. Military Recruits. *Military Medicine, 181*(6), 512–523. doi: 10.7205/MILMED-D-15-00143

Neal, M., Fleming, N., Eberman, L., Games, K., & Vaughan, J. (2016). Effect of body-weight-support on lower-limb biomechanics. *Journal of Orthopaedic & Sports Physical Therapy, 46*(9), 784–793.

Nogueras Miranda, M., Grande Rodríguez, I., & Cordente Martínez, C. A. (2018). Identificación de fases en la carrera de 100 m lisos en función de variables cinemáticas y dinámicas. Cultura, ciencia y deporte. *Revista de ciencias de la actividad física y del deporte de la Universidad Católica de San Antonio*, *37*, 39–50

Page, M. (2013). Plantar pressure measures of running and cutting movements on third-generation artificial turf and natural grass. (Unpublished master's thesis). University of Chester, United Kingdom. Hdl.handle.net. [accessed March 13, 2019]. Available at: http://hdl.handle.net/10034/320297

Paredes Hernández, V., Martos Varela, S., & Romero Moraleda, B. (2011). Propuesta de Readaptación para la Rotura del Ligamento Cruzado Anterior en Fútbol. *Revista Internacional de Medicina y Ciencias de La Actividad Física y El Deporte, 11*, 573–591.

Pires, N., Lay, B., & Rubenson, J. (2014). Joint-level of the walk to run transition in humans. *The Journal of Experimental Biology, 217*, 3519–3527

Pourahmadi, M. R., Taghipour, M., Jannati, E., Mohseni-Bandpei, M. A., Ebrahimi Takamjani, I., & Rajabzadeh, F. (2016). Reliability and validity of an iPhone(®) application for the measurement of lumbar spine flexion and extension range of motion. Peer J, 4, e2355.

Rajakaruna, R. M. B. D., Arulsing, W., Oliver Raj, J., & Sinha, M. (2015). A study to correlate clinically validated normalized truncated navicular height to brody's navicular drop test in characterizing medial arch of the foot. *BMR Medicine, 1*(1),1–7.

Romero-Franco, N., Martínez-Amat, A., & Martínez-López, E. J. (2013). Efecto del entrenamiento propioceptivo en atletas velocistas. *Revista Internacional de Medicina y Ciencias de La Actividad Física y El Deporte, 13*(51), 437–451.

Ruschel, C., Haupenthal, A., Hubert, M., De Brito Fontana, H., & Roesler, H. (2010). Loading forces in shallow water running at two levels of immersion. *Journal of Rehabilitation Medicine, 42*(7), 664–669.

Sáez de Villareal, E., Suárez-Arrones, L., Requena, B., Haff, G. G., & Ferrete, C. (2015). Effects of plyometric and sprint training on physical and technical skill performance in adolescent soccer players. *The Journal of Strength & Conditioning Research*, 29(7), 1894–1903.

Skelton, J. (2000). The function of the discussion section in academic medical writing. *British Medicine Journal,* 20(7244), 1269–1270.

Stöggl, T., & Martiner, A. (2016). Validation of Moticon's OpenGo sensor insoles during gait, jumps, balance and cross-country skiing specific imitation

PENDIENTE DE PUBLICACIÓN / IN PRESS

movements. *Journal of Sports Sciences*, 1–11. doi: 10.1080/02640414.2016

Stolwijk, N. M., Duysens, J., Louwerens, J., W., & Keijsers, N. L. (2010). Plantar pressure changes after long-distance walking. *Medicine and Science in Sports and Exercise, 42*(12), 2264–2272.

Taunton, J. E., Ryan, M. B., Clement, D. B., McKenzie, D. C., & Lloyd-Smith D. R. (2002). A retrospective case-control analysis of 2002 running injuries. *Sports Medicine*, 95–102.

Tessutti, V., Trombini-souza, F., Ribeiro, A. P., Nunes, A. L., De Camargo, I., & Sacco, N. (2010). In-shoe plantar pressure distribution during running on natural grass and asphalt in recreational runners. *Journal of Science and Medicine in Sports*. doi: 10.1016/j.jsams.2008.07.008

Tessutti, V., Ribeiro, A. P., Trombini-Souza, F., & Sacco, I. C. (2012). Attenuation of foot pressure during running on four different surfaces: asphalt, concrete, rubber, and natural grass. *Journal of Sports Sciences, 30*(14), 1545–1550.

Van Caekenberghe, I., De Smet, K., Segers, V., & De Clercq, D. (2010). Overground vs. Treadmill walk-to-run transition. *Gait and Posture, 31*, 420–428.

Velotta, J., Weyer, J., Ramirez, A., Winstead, J., & Bahamonde, R. (2011). Relationship between leg dominance tests and type of task. *Portuguese Journal of Sport Sciences, 11*(Supl. 2), 1035–1038.

Wang, L., Hong, Y., Li, J. X., & Zhou, J. H. (2012). Comparison of plantar loads during running on different overground surfaces. *Research in Sports Medicine, 20*(2), 75–85. doi: 10.1080/15438627.2012.660816

WMA - The World Medical Association–Manual de Etica Médica (2019). Wma.net. [Accessed March 12 2019]. Available at: https://www.wma.net/es/que-hacemos/educacion/manual-de-etica-medica/

Zulkifli S., & Loh W. (2018). A state-of-the-art review of foot pressure. *Foot and Ankle Surgery,* doi: 10.1016/j.fas.2018.12.005

Número de citas totales / Total References: 39 (100%)
Número de citas propias de la revista /Journal´s own references: 2 (5,12%)

PENDIENTE DE PUBLICACIÓN / IN PRESS