Revista de Educação Física
Journal of Physical Education
Home page: www.revistadeeducacaofisica.com

Original Article

Artigo Original

Influence of the Foot and its Characteristics on the Risk of Injury Associated with Dynamic Balance in Soccer Players: An Observational Study

Influência do pé e suas características no risco de lesões associadas ao equilíbrio dinâmico em jogadores de futebol: um estudo observacional

Miguel Angel Campo Ramírez[1,§]Esp; Gabriel Hernandez Oñate[1] MSc; David Eliecer Lopez Salamanca[1] MSc; Olga Lucia Hincapie[1] MSc; Camilo Medina Escarria[1] Esp; Jaime Andrés Perdomo[2] Esp

Received: May 10, 2021. Accepted: October 4, 2021.
Published online: Oct 19, 2021.
DOI: 10.37310/ref.v90i3.2758

Abstract

Introduction: Dynamic balance (DB) is the basis for all sports motor activities. Variables such as the type of foot and the windlass mechanism (WM) could influence this balance and therefore the risk of injury to the lower limb. Currently no studies are reported that relate these elements to each other in soccer players.

Objective: To determine the influence of some characteristics of the foot on the risk of injury associated with DB in young soccer players.

Methods: Observational, cross-sectional, and correlational study. Forty players were included in the male sub 20 category. DB was evaluated by means of the Y balance test (YBT). To determine the type of the foot, the Herzco method and Jack's test were used to evaluate the WM.

Results: Statistically significant differences were found between the type of the foot and the Jack test with some scopes of the YBT. There was a significant relationship between the left WM *vs* left DB.

Conclusion: Foot's type and the WM influence the DB. The WM could be related to the DB, however, there seems to be no relationship between Hallux's evaluation and foot type with the DB. Variables such as the quality of execution of the sporting gesture, exposure to load, among others, should be considered when studing the issue.

Key Points

- Foot's type and windlass mechanism (WM) influence the dynamic balance (DB).

- There seems to be no relationship between Hallux's evaluation and foot type with the DB.

- Quality of execution of the sporting gesture, exposure to load, among others, should be considered when studing the issue.

Keywords: football, foot, rehabilitation, postural balance, athletic injuries.

Resumo

Introdução: O equilíbrio dinâmico (ED) é a base para todas as atividades motoras esportivas. Variáveis como o tipo de pé e o mecanismo do molinete (MM) podem influenciar nesse equilíbrio e, portanto, no risco

[§]Corresponding Author: Miguel Angel Campo Ramírez – e-mail: miguel.campo@endeporte.edu.co
*Translator: Lorena Mejía Salazar – lorena.lmtranslation@gmail.com
Affiliations: [1]Facultad de Salud y Rehabilitación, Institución Universitaria Escuela Nacional del Deporte. Cali, Colombia; [2]Club Deportivo América de Cali S.A.

de lesão do membro inferior. Atualmente não são relatados estudos que relacionem esses elementos entre si em jogadores de futebol.

Objetivo: Verificar a influência de algumas características do pé no risco de lesões associadas ao ED em jovens jogadores de futebol.

Métodos: Estudo observacional, transversal e correlacional. Quarenta jogadores foram incluídos na categoria sub 20 masculina. O ED foi avaliado por meio do teste de equilíbrio em no teste de equilíbrio em Y (TEY). Para determinar o tipo de pé, o método de Herzco e o teste de Jack foram usados para avaliar MM.

Resultados: Foram encontradas diferenças estatisticamente significativas entre o tipo de pé e o teste de Jack com alguns osciloscópios do YBT. Houve uma relação significativa entre o MM esquerdo *vs* ED esquerdo.

Conclusão: O tipo do pé e o MM influenciam o ED. O MM pode estar relacionado ao ED, no entanto, parece não haver relação entre a avaliação de Hallux e o tipo de pé com o ED. Variáveis como qualidade de execução do gesto esportivo, exposição à carga, entre outras, devem ser consideradas no estudo do assunto.

Pontos Chave

- O tipo de pé e o mecanismo de molinete (WM) influenciam o equilíbrio dinâmico (DB).

- Parece não haver relação entre a avaliação de Hallux e o tipo de pé com o DB.

- Qualidade de execução do gesto esportivo, exposição à carga, entre outros, devem ser considerados ao estudar o assunto.

Palavras-chave: futebol, pé, reabilitação, equilíbrio postural, lesões atléticas.

Influência do pé e suas características no risco de lesões associadas ao equilíbrio dinâmico em jogadores de futebol

Introduction

Dynamic balance is understood as the moment in which inertial forces intervene in order not to fall or lose balance (1). Some authors mention that the ability to balance is the basis for all sports motor activities and is recognized as a predictor of lower limb injury (2,3). It is estimated that approximately three to five million sports injuries to the lower limb occur in elite training men's soccer each year, especially ankle sprains (4,5). Those injuries usually occur without contact, where dynamic balance plays a fundamental role in the control and regulation of these situations during sports practice (4,5). Dynamic balance requires vestibular, proprioceptive, and visual information to provide neuromuscular adjustments and maintain the center of mass within the base of support (6). It is also influenced by physical characteristics such as anthropometric differences, previous injuries, range of motion, strength, neuromuscular control, proprioception and sex. (6).

Balance also is affected by the foot because that structure links the human body (bipedal position) with the external environment generating adequate weight distribution during many static and dynamic body movements through its structures that absorb impacts, such as the transverse, longitudinal, medial and lateral arches (7).

According to different studies, flat feet can cause dysfunctions in the posterior tibial tendon sheath, evidenced by dynamic imbalance, pain, joint involvement (8) and even stress fractures (9). The flat foot also generates a tendency towards pronation and an eversion of the heel causing a greater load on the medial compartment of the foot. This structural deformation limits the ability to absorb impacts, reducing the sensation of balance and dynamic stability when walking or running (10). Some characteristics of the foot can favor the development of flat feet, such as the

windlass mechanism (WM)[1] , which assesses the behavior of the medial longitudinal arch when performing a passive extension of the Hallux(11). If this mechanism is not activated (positive test), an increase in the probability of suffering foot injuries is reported, especially if the player presents a high sports performance (11). The causes of these sports injuries could have an origin in the dynamic imbalance.

Some studies have compared the relationship of foot type with dynamic balance in healthy individuals: athletes and non-athletes with musculoskeletal injuries (7,11,12). Nevertheless, literature does not exhibit evidence of the influence of foot's characteristics in relation to the risk of injury associated with dynamic balance in soccer players, in despite the existence of a theoretical, anatomical, and functional relationship among those variables.

The objective of the research was to establish the relationship between some characteristics of the foot and the risk of injury through dynamic balance in young soccer players

Methods

Study design and sample

Cross-sectional observational study with a convenience sample composed by 40 soccer players of sub 20 A and B categories of the América club in Cali, Colombia. Active players over 18 years of age who voluntarily consent to participation are included in the study; Players who presented any pathology at the time of assessment, considerable postural alteration or who had presented an injury to the lower limb in a period equal to or less than three months were excluded.

Ethical aspects

All ethical principles of research involving human beings were fully observed in the present study contained in Resolution 8430 of 1993 issued by the Ministry of Health of Colombia. The study was approved by the Ethics Committee of a University Institution with code 4.1.01.03.06.

Study variables

Injury risk was the outcome variable. Arch of mobility (AMA) of hallux, foot type, dynamic balance, and windlass mechanism were the exposure variables. Sociodemographic, anthropometric, sports data (performance in games), age, social stratum, weight, height, body mass index (BMI), playing position, training frequency in days, and dominance were the covariables used to describe the sample.

Injury risk

To determine the risk of injury (outcome), the reach distances of the Y-balance test (3) were normalized with the lower limb length measurement according to the Plisky protocol (16,17) through the following formula: Composite Normalized Reach Distance (DANC)% = (Anterior Distance + Posteromedial Distance + Posterolateral Distance) / (3 x actual measurement of lower limb)*100. According to the methodology, for each limb, a% DANC lower than 90%, it was related to a deficit in neuromuscular control and a greater probability of injuries in said limb.

Foot characteristics

Arch of mobility (AMA) of hallux

The hallux AMA (exposure variable) was assessed using simple goniometry (13).

Windlass mechanism (WM)

The WM (exposure variable) was evaluated using the Jack or Hubscher test

[1]*Editorial note*: About Windlass Mechanism (WM) Bolgla & Malonea[1] explained that WM "*describes the manner by which the plantar fascia supports the foot during weight- bearing activities and provides information regarding the biomechanical stresses placed on the plantar fascia*."

[1]Bolgla LA, Malone TR. Plantar Fasciitis and the Windlass Mechanism: A Biomechanical Link to Clinical Practice. Journal of Athletic Training. 2004;39(1): 77–82.

through a protocol consisting of three attempts(11).

Foot type

Foot type (exposure variable) was evaluated using the Herzco method (15), where it is classified according to perpendicularity criteria into the following foot type categories: flat, normal flat, normal, normal cavus , cavus, strong cavus and extreme cavus. For this, it was necessary to print the footprint.

Dynamic balance

The dynamic balance (exposure variable) was evaluated using the Y balance test (3). Before starting the information collection process, the researchers were trained in the application of the Y balance test to avoid possible biases and to standardize the procedure.

Experimental procedures

For data collection, three phases were used: the first phase began with the recording of sociodemographic, anthropometric and sports data through an interview, in which variables such as age, stratum, weight, height, body mass index (BMI), playing position, training frequency in days and dominance. We continued with the assessment of the AMA of hallux by means of simple goniometry (13), WM that was evaluated by means of the Jack or Hubscher test through a protocol consisting of three attempts. Result is the evaluation that is presented twice, classifying as negative, if there is an increase in the medial longitudinal arch, or positive if this condition does not appear.

For the second phase, the impression of the footprint (14) was taken, it was made on thermal paper, moistening the sole of each player's foot with alcohol, leaving the details and the silhouette of the footprint well defined, by means of which. The lower limbs were measured of the of each athlete from the navel to the tibial malleolus was also evaluated (16).

In the last phase, the dynamic balance assessment was carried out through the application of the Y balance test (3). Before starting the information collection process, the researchers were trained in the application of the Y balance test to avoid possible biases and to standardize the procedure. Each participant was explained the correct way to develop the movement, they were allowed to perform a test attempt for each direction, then three minutes of rest were allocated before starting the test, then three correct attempts were made for each direction, posterolateral (PL), posteromedial (PM), and anterior (A); each attempt was separated by 30 seconds of recovery; the maximum total number of attempts was three per address.

Statistical analysis

The data were analyzed using the statistical package SPSS version 20.0 (Inc. Chicago, Illinois). The statistical methods used for the univariate analysis of the results were broken down considering that the categorical variables were presented in the form of frequency and percentage. For the numerical variables, the Kolmogorov Smirnov normality test was performed considering the sample size. Data with normal distribution were presented as mean ± standard deviation and data with non-normal distribution were presented as median and interquartile range (IQR).

To explore the relationships, Wilcoxon non-parametric hypothesis tests were used to compare a dichotomous categorical variable with a numerical non-normal distribution, setting a 95% confidence interval. The Kruskal Wallis test was used to compare polytomous categorical variables with numerical variables of non-normal distribution. For the comparison of categorical variables, Fisher's exact test was used. Statistical significance was expressed by the value P <0.05.

Results

More than a third of the sample were from low socioeconomic level, three-quarters of the population have right-hand dominance and more than the right. half of the population occupy the midfielder position. Mean of age was of 19±0,94 years old, the weight 71±5.1 Kg and height 177.3±4.8, In the BMI variable, more than 75% of the participants exceeded the coefficient of 21.6 (Table 1).

Fifity-eight percent of the participants had the WM absent (positive test) for the lower right limb, likewise in the lower left limb 65% had it absent. Furthermore, 75% of soccer players present a hallux extension greater than 48 and 50 degrees for the right and left feet respectively. Regarding the evaluation of dynamic balance when supporting the left limb, the population presents larger displacements in the three axes (Table 2 and Table 3).

There was a statistically significant relationship of the left WM with the risk of injury to the left limb. No significant relationship was found between Hallux AMA and foot type with the risk of lower limb injury. (Table 4).

Of the participants who were at risk of injury to the left limb, 55% had a left cavus foot, followed by a normal left foot with 36.3%. In the right limb, of the patients who presented risk of injury, 47% presented cavus foot and 41% normal foot. (Table 5).

Table 1 – Demographic and sports characteristics of the male sub-20 team of América de Cali club, 2020

Variables	**n**	**%**
Socioeconomic stratum		
Low (1 and 2)	15	38
Medium (3 and 4)	9	23
High (5 and 6)	16	39
Laterality		
Right	30	75
Left	9	23
Ambidextrous	1	2
Position game		
Goalkeeper	1	2
Defense	13	32
Midfielder	21	52
Forward	5	12

Table 2 – Characteristics of the foot

Variable	**MMII Right**		**MMII Left**	
	n	**%**	**n**	**%**
Windlass Mechanism (WM) (Jack Test)				
Positive	23	57.5	26	65
Negative	17	42.5	14	35
Foot type				
Flay	4	10.0	3	7
Normal	19	48.0	19	48
Cavus	17	42.0	18	45

Table 3 – Characteristics dynamic balance and arch of mobility (AMA) of hallux

Variable	**MMII Right**	**MMII Left**
AMA Hallux extension (º)*	47.3±5	48.8±8.3
Y Balance Test		
Anterior Reach (cm)*	69.6 ±5.3	72.9 ±7.3
Posteromedial Reach (cm)*	98.7 ±4.1	104.8 ± 10.3
Posterolateral Reach (cm)*	100.0 ± 13	103.4±12

*Variable expressed with mean ± standard deviation

Table 4. Bivariate analysis between AMA Hallux extension with the risk of injury for MMII

Variable	No risk of injury	At risk of injury	Est	*P*
AMA Hallux extension Left (°)*	48(40-55)	50(43-62)	Wx: -1.125	0.26
AMA Hallux Right (°)*	48(42-52)	48(43-52)	Wx: -0.330	0.74

*Variable expressed with Median (Interquartile range = Quartile1-Quartile3). Wx = Wilcoxon-Mann-Whitney test. MMII = lower limb

Table 5 – Bivariate analysis between anthropometric characteristics of the foot with the risk of injury for MMII

Variable	No risk of injury		At risk of injury		Est	p
	n	%	n	%		
Foot type (left foot)						
Plane	2	7.0	1	9.0	Fisher:	0.662
Normal	15	51.7	4	36.3	0.7546	
Cavus	12	41.3	6	54.6		
Foot type (right foot)						
Plane	2	9.0	2	12.0	Fisher:	0.901
Normal	12	52.1	7	41.1	0.4855	
Cavus	9	39.1	8	47.0		
Windlass mechanism (Test Jack, left foot)						
Positive	22	75.8	4	36.3	Fisher:	**0.030**
Negative	7	24.0	7	63.6	5.4690	
Windlass mechanism (Test Jack, right foot)						
Positive	16	70.0	7	41.0	Fisher:	0.110
Negative	7	30.0	10	58.8	3.2237	

Statistically significant relationships (p<0.05) were observed between the type of the foot and the WM with the PL range of the Y balance test in the lower right limb, as well as between the WM and the A and PL ranges of the lower left limb. (See table 6 and 7 in the appendix)

Discussion

The main finding was that statistically significant differences were found between the type of foot and the right Jack test with the PL reaches of the Y balance test in the right lower limb. Also, between the left Jack test and the A and PL ranges of the lower left limb. There was a statistically significant relationship between the risk of injury and the windlass mechanism in the left limb. Finally, there was no statistically significant relationship between variables such as: type of foot and range of motion of the Hallux vs the risk of injury associated with dynamic balance.

Regarding the type of foot, the results of the present investigation are similar to those found in Spain by Gonzales et al, in 2017 where, with a sample of 1,002 participants, 68.2% had normal feet. However, it differs with 19% flat feet. (18) Because in our sample there was not a high prevalence of 9% flat feet, which could be related to the results of the relationship between the type of foot and the risk of injury through dynamic balance. Therefore, another possible line of work would be to identify the relationship between these variables with a sample whose foot type characteristics have greater variability

among themselves (normal foot, flat foot, cavus, etc.).

In this regard, in 2013 Jasper and Kong in a systematic review established that both flat foot and cavus foot are significantly associated with the risk of injury, however they describe the relationship as low (19). Toullec in 2019 related flat feet with the appearance of knee pain and low back pain (20); other studies have associated flat feet with long-term femorotibial cartilage damage in athletes (21). In turn, the cavus foot is recognized as one of the biomechanical factors that influences the appearance of stress fractures (22).

Some studies, such as Rivera et al., Have reported a statistically significant relationship between the type of foot and the prevalence of lower limb injuries in athletes (23). However it should be clarified that in these studies the type or classification described as pronated foot, normal or supinate (24).

Although the previous studies present population and methodological differences in the identification of risk, they all relate the morphological types of foot with the appearance of musculoskeletal injuries. Possibly in this study no such relationship was found because the risk of injury is determined solely by the dynamic balance as a function of the DANC%, which takes into account the differences in the ranges with respect to the length of the limb without considering other potentially influential variables such as age, type of sport, exposure to load, among others.

The results compared to the laterality of the participants in the present investigation agree with the study carried out by Ponce et al. in Chile, year 2019, where 90% of evaluated soccer players presented dominance of the right leg (25). Like the study by Quintero et al. of 2020 in Colombia, where 74.2% of the participating footballers in the under 16 and under 17 categories were predominantly rights (26). In relation, some studies have reported that in soccer players, muscle injuries of the hamstrings and adductors occur more frequently in the dominant leg (27,28).

Faced with the characteristics of the foot and the dynamic balance of the population, the results of Jack's test obtain values that differ from those found by some authors such as Gómez in 2020, where with a sample of 100 soccer players, 79% of the population presented a negative Jack test, that is, the presence of the windlass mechanism (29). Furthermore, this variable was not related to the risk of injury to both lower extremities. In 2000, Fuller presented a model based on the Jack's test that allows to propose the mechanical cause and a possible treatment approach for plantar fasciitis, hallux stiffness, and hallux valgus, however this model has limitations to predict the risk of suffering from the pathologies (30); Alfaro et al, evidenced that although Jack's test shows a trend in relation to sever heel pain, it does not show a statistically significant relationship for its incidence in soccer players (31). However, De la Cruz et al. In 2017, they report a statistically significant relationship between the windlass mechanism and the risk of injury in the lower extremities, this relationship becomes stronger when athletes are high-performance athletes (11).

On the other hand, Aranda et al mention that the participants with plantar fasciitis presented less extension of the hallux, however it cannot be established that the limitation of this range of motion is a cause or effect of plantar fasciitis, in addition to the relationship of the alignment of the plantar fasciitis. foot, in this case pronated or supinated (32). In this regard, Frimenko et al developed a relationship curve between the mobility of the hallux and the risk of injury to the phalangeal metatarsal joint, pointing out that at 78° of extension there is a 50% probability of injuring the joint; however, related aspects of AMA are not described based on the prediction of the risk of injury (33).

The literature relating the Jack test and the Hallux AMA to injury risk is considered to be limited. No conclusive aspects are found that relate these variables to each other. It is also possible that athletes functional asymmetries between both

Hallux, however still a clear association between the presence of these asymmetries and prediction or susceptibility to injury of the lower member (34).

In the comparison of the Y Balance Test scopes according to the laterality of the lower limbs, no statistically significant differences were found. Likewise, there is no conclusive literature that relates these variables in the sports population. The studies found relate laterality with the risk of injury (35).

Regarding dynamic balance, in the present investigation statistically significant differences were found between the posterolateral reaches of the Y Balance Test in the right lower limb and the type of foot. In relation to Hertel et al, in 2002 they reported that participants with cavus feet present significantly higher pressure centers compared to flat feet (36). This could translate into changes in dynamic balance. However, other studies are required to confirm this hypothesis.

Additionally, statistically significant differences were found between the posterolateral reaches in the left and right lower limb in relation to Jack's test. Also, in the anterior reach of the lower left limb. These findings could indicate that the dynamic balance is affected by the WM in some reaches, that is, that the structures of the calcaneus, the midtarsal joint and the head of the first metatarsal can influence the mechanics of the joints enough to alter stability limits during dynamic activities. However, the literature that relates the Jack test and the Y Balance Test are limited, and no conclusive aspects were found that relate these two variables.

Finally, in relation to the limitations of the study, the low prevalence of flat feet in the sample is recognized, which could affect the relationships found in the results. Difficulties of the type of cross-sectional study to find causal associations prior to measurements were also reported.

Strong points and limitations of the study

One of the strengths of this study was the approach examining the relationship of anatomical and functional characteristics with elements such as dynamic balance in soccer athletes. The results contributed to knowledge on dynamic balance and how it can vary according to the type of foot. Future research should investigate correlation of those aspects with sports' injury prevention.

As a limitation of the study, one can consider that the risk of injury is determined by dynamic balance without contemplating other potentially influential variables such as dynamic knee valgus, muscular imbalances, age, among others, analysis that should be examined in future studies.

Conclusion

The objective of the research was to establish the relationship between foot characteristics and the risk of injury through dynamic balance in young soccer players. Results showed that lower right limb PL reaches of the Y test differ according to the type of foot. For the left lower limb there were significant differences in the PL and A ranges. In both lower limbs the ranges significantly varied according to the presence or absence of the windlass mechanism. It is plausible that such characteristics influence the dynamic balance in soccer players. This could explain the statistically significant relationship found between the risk of injury to the left limb and the left windlass mechanism. However, no relationship was found between the other characteristics of the foot (Hallux AMA and foot typology) with the risk of lower limb injuries, possibly because said risk is determined solely by dynamic balance as a function of the DANC%, in which the differences in the reaches with respect to the length of the limb are taken into account without considering other potentially influential variables such as age, type of sport, exposure to load, among others. The implications of this influence on functional performance and the risk of injury during sport are not yet clear and require further studies. Finally, factors such as the type of the foot and the WM should be considered in the review of the intrinsic aspects that can influence functional performance,

generating biomechanical alterations that increase the risk of injury in dynamic actions.

Acknowledgements

To the América de Cali SA Sports Club for participating in the project.

Conflict of interests

The researchers declare that they have no conflict of interest of any kind.

Funding statement

The National School of Sports University Institution of Cali, Colombia provided financial support in each phase of the project.

References

1. Cos F, Cos MÀ, Buenaventura L, Grivé RP. Modelos de análisis para la prevención de lesiones en el deporte. Estudio epidemiológico de lesiones: el modelo Union of European Football Associations en el fútbol. Apunts: *Medicina de l'esport*. [Online] 2010; 95–102. Available from: https://www.raco.cat/index.php/Apunts/article/view/196613 [Accessed: 2nd July 2020]

2. Mateos NC. *Evaluación del equilibrio dinámico en Educación Infantil*. : 26. Available from: https://digibug.ugr.es/bitstream/handle/10481/40783/C%F3zar_Mateos_Natalia.pdf;jsessionid=AD5E60CC4538C24F0D234A69C9858DAB?sequence=1

3. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a Predictor of Lower Extremity Injury in High School Basketball *Players. Journal of Orthopaedic & Sports Physical Therapy*. [Online] 2006;36(12): 911–919. Available from: doi:10.2519/jospt.2006.2244 [Accessed: 2nd July 2020]

4. Powden CJ, Dodds TK, Gabriel EH. The reliability of the star excursion balance test and lower quarter Y-Balance Test in healthy adults: a systematic review. International *Journal of Sports Physical Therapy*. [Online] 2019;14(5): 683–694. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6769278/ [Accessed: 2nd July 2020]

5. Roos KG, Wasserman EB, Dalton SL, Gray A, Djoko A, Dompier TP, et al. Epidemiology of 3825 injuries sustained in six seasons of National Collegiate Athletic Association men's and women's soccer (2009/2010–2014/2015*). British Journal of Sports Medicine*. [Online] 2017;51(13): 1029–1034. Available from: doi:10.1136/bjsports-2015-095718 [Accessed: 2nd July 2020]

6. Fusco A, Giancotti GF, Fuchs PX, Wagner H, da Silva RA, Cortis C. Y balance test: Are we doing it right? *Journal of Science and Medicine in Sport*. [Online] 2020;23(2): 194–199. Available from: doi:10.1016/j.jsams.2019.09.016 [Accessed: 22nd June 2020]

7. Hyong IH, Kang JH. Comparison of dynamic balance ability in healthy university students according to foot shape. *Journal of Physical Therapy Science.* [Online] 2016;28(2): 661–664. Available from: doi:10.1589/jpts.28.661 [Accessed: 2nd July 2020]

8. Kim J, Lim O, Yi C. Difference in static and dynamic stability between flexible flatfeet and neutral feet. *Gait & Posture*. [Online] 2015;41(2): 546–550. Available from: doi:10.1016/j.gaitpost.2014.12.012 [Accessed: 2nd July 2020]

9. Yoon K-S, Park S-D. The effects of ankle mobilization and active stretching on the difference of weight-bearing distribution, low back pain and flexibility in pronated-foots subjects. *Journal of Exercise*

Rehabilitation. [Online] 2013;9(2): 292–297. Available from: doi:10.12965/jer.130013

10. Kirby KA. Sistema de reparto de cargas del arco longitudinal del pie. *Revista Española de Podología*. [Online] 2017;28(1): 37–45. Available from: doi:10.1016/j.repod.2017.03.002 [Accessed: 2nd July 2020]

11. De La Cruz GY. *Relación entre pie plano y equilibrio dinamico en los estudiantes de la I.E Nuestra Señora del Carmen, Lima - 2017*. [Online] [Tesis] [Chimbote - Perú]: Universidad San Pedro; 2018. Available from: http://repositorio.usanpedro.edu.pe/bitstream/handle/USANPEDRO/12018/Tesis_60465.pdf?sequence=1&isAllowed=y

12. Tran K, Spry C. *Custom-Made Orthoses versus Prefabricated foot Orthoses: A Review of Clinical Effectiveness and Cost-Effectiveness*. [Online] Ottawa (ON): Canadian Agency for Drugs and Technologies in Health; 2019. Available from: http://www.ncbi.nlm.nih.gov/books/NBK549527/ [Accessed: 2nd July 2020]

13. Deborah A. Nawoczenki, judith F. Baumhauer, Brian R. Umberger. Relationship Between Clinical Measurements and Motion of the First Metatarsophalangeal *Joint During Gait*. 1999; 370–376. Available from: doi:10.2106/00004623-199903000-00009

14. Diéguez SL, Sánchez AJL, Sánchez MLZ, Martínez-López EJ. *Análisis de los diferentes métodos de evaluación de la huella plantar*. 2011; 6. Available from: https://www.redalyc.org/pdf/3457/345732285010.pdf

15. Neal BS, Griffiths IB, Dowling GJ, Murley GS, Munteanu SE, Franettovich Smith MM, et al. Foot posture as a risk factor for lower limb overuse injury: a systematic review and meta-analysis. *Journal of Foot and Ankle Research*. [Online] 2014;7(1): 55. Available from: doi:10.1186/s13047-014-0055-4 [Accessed: 2nd July 2020]

16. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to Assess Dynamic Postural-Control Deficits and Outcomes in Lower Extremity Injury: A Literature and Systematic Review. *Journal of Athletic Training*. [Online] 2012;47(3): 339–357. Available from: doi:10.4085/1062-6050-47.3.08 [Accessed: 2nd July 2020]

17. Gribble PA, Hertel J. Considerations for Normalizing Measures of the Star Excursion Balance Test. Measurement in Physical *Education and Exercise Science*. [Online] 2003;7(2): 89–100. Available from: doi:10.1207/S15327841MPEE0702_3 [Accessed: 2nd July 2020]

18. Gonzalez-Martin C, Pita-Fernandez S, Seoane-Pillado T, Lopez-Calviño B, Pertega-Diaz S, Gil-Guillen V. Variability between Clarke's angle and Chippaux-Smirak index for the diagnosis of flat feet. *Colombia Médica : CM*. [Online] 48(1): 25–31. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5438225/ [Accessed: 2nd July 2020]

19. Tong JWK, Kong PW. Association Between Foot Type and Lower Extremity Injuries: Systematic Literature Review With Meta-analysis. *Journal of Orthopaedic & Sports Physical Therapy*. [Online] 2013;43(10): 700–714. Available from: doi:10.2519/jospt.2013.4225 [Accessed: 22nd June 2020]

20. Toullec E. Pie plano valgo estático del adulto (incluidas las sinostosis

congénitas). EMC - *Aparato Locomotor*. [Online] 2019;52(3): 1–12. Available from: doi:10.1016/S1286-935X(19)42726-3 [Accessed: 2nd July 2020]

21. Gross KD, Felson DT, Niu J, Hunter DJ, Guermazi A, Roemer FW, et al. Association of flat feet with knee pain and cartilage damage in older adults. *Arthritis Care & Research*. [Online] 2011;63(7): 937–944. Available from: doi:10.1002/acr.20431 [Accessed: 22nd June 2020]

22. Grande del Arco J. Fracturas de estrés en atletas. *Revista Internacional de Ciencias Podológicas*. [Online] 1970;12(2): 63–71. Available from: doi:10.5209/RICP.59825 [Accessed: 2nd July 2020]

23. Miguel-Andrés I, Rivera-Cisneros AE, Mayagoitia-Vázquez JJ, Orozco-Villaseñor SL, Rosas-Flores A. Índice de pie plano y zonas de mayor prevalencia de alteraciones músculo-esqueléticas en jóvenes deportistas. *Fisioterapia*. [Online] 2020;42(1): 17–23. Available from: doi:10.1016/j.ft.2019.08.002 [Accessed: 2nd July 2020]

24. Jorge Camilo Cedeño Vargas. *Estudio podológico y biomecánico que descubre el uso de calzado inadecuado que afecta la práctica deportiva*. [Online] [Guayaquil]: Universidad de Guayaquil; 2019. Available from: http://repositorio.ug.edu.ec/handle/redug/39559

25. Álvarez-Ponce D, Guzmán-Muñoz E. *Efectos de un programa de ejercicios excéntricos sobre la musculatura isquiotibial en futbolistas jóvenes*. : 6. Available from: http://archivosdemedicinadeldeporte.com/articulos/upload/or03_alvarez_ponce.pdf

26. Laura Andrea Quintero Palma, Wilfredo Agredo Rodriguez, Jessica Quiceno henao, Alexander Quiñones, José fernando Tovar. Efectos de fatiga en variables cinemáticas y cinéticas de miebros inferiores en jugadores de fútbol. *REIA*. 2020;17(33): 1–13. Available from: doi:https://doi.org/10.24050/reia.v17i33.1360

27. Svensson K, Eckerman M, Alricsson M, Magounakis T, Werner S. Muscle injuries of the dominant or non-dominant leg in male football players at elite level. *Knee Surgery, Sports Traumatology, Arthroscopy*. [Online] 2018;26(3): 933–937. Available from: doi:10.1007/s00167-016-4200-4 [Accessed: 22nd June 2020]

28. Pangrazio O, Forriol F. Epidemiología de las lesiones sufridas por los jugadores durante el XVI Campeonato Sudamericano Sub-17 de Fútbol. *Revista Española de Cirugía Ortopédica y Traumatología*. [Online] 2016;60(3): 192–199. Available from: doi:10.1016/j.recot.2015.12.002 [Accessed: 2nd July 2020]

29. Herrera G, Fabrizzio K. *Incidencia de Fascitis Plantar y su relación con el Hallux Limitus Funcional en los jugadores del Centro de Formación Técnica de Futbol*: 71. Available from: http://repositorio.ucsg.edu.ec/handle/3317/14325

30. Fuller E. The windlass mechanism of the foot. A mechanical model to explain pathology. Journal of the American *Podiatric Medical Association*. [Online] 2000;90(1): 35–46. Available from: doi:10.7547/87507315-90-1-35 [Accessed: 22nd June 2020]

31. Alfaro Santafé J, Gómez Bernal A, Alfaro Santafé J-V, Lanuza Cerzócimo C, Escamilla Galindo V-L, Almenar Arasanz A-J. Relación de

Lunge y Jack Test en la apófisis calcánea (Talalgia de Sever) en futbolistas jóvenes. *Revista Internacional de Ciencias Podológicas*. [Online] 2017;11(2): 117–123. Available from: doi:10.5209/RICP.56028 [Accessed: 22nd June 2020]

32. Aranda Y, Munuera PV. Plantar Fasciitis and Its Relationship with Hallux Limitus. *Journal of the American Podiatric Medical Association*. [Online] 2014;104(3): 263–268. Available from: doi:10.7547/0003-0538-104.3.263 [Accessed: 22nd June 2020]

33. Frimenko RE, Lievers WB, Riley PO, Park JS, Hogan MV, Crandall JR, et al. Development of an Injury Risk Function for First Metatarsophalangeal Joint Sprains: *Medicine & Science in Sports & Exercise*. [Online] 2013;45(11): 2144–2150. Available from: doi:10.1249/MSS.0b013e3182994a10 [Accessed: 22nd June 2020]

34. Gkrilias P, Zavvos A, Fousekis K, Billis E, Matzaroglou C, Tsepis E. Dynamic balance asymmetries in pre-season injury-prevention screening in healthy young soccer players using the Modified Star Excursion Balance Test—a pilot study. Journal of Physical *Therapy Science*. [Online] 2018;30(9): 1141–1144. Available from: doi:10.1589/jpts.30.1141 [Accessed: 22nd June 2020]

35. Murphy D, Connolly D, Beynnon B. Risk factors for lower extremity injury: a review of the literature. *British Journal of Sports Medicine*. [Online] 2003;37(1): 13–29. Available from: doi:10.1136/bjsm.37.1.13 [Accessed: 2nd July 2020]

36. Hertel J, Gay MR, Denegar CR. Differences in Postural Control During Single-Leg Stance Among Healthy Individuals With Different Foot Types. *Journal of Athletic Training*. [Online] 2002;37(2): 129–132. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC164334/ [Accessed: 2nd July 2020]