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ORIGINAL ARTICLE

Comparison of Plantar Dynamics during Four Sports Gestures in Rugby Players

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ABSTRACT

Background. Four of the most relevant gestures in rugby (RU) are the pass, the tackle, the line out, and the scrum. RU is the third most common contact sport on the planet and, being a fast-paced collision game, it carries a high risk of injury. **Objectives.** To describe and compare plantar dynamics during four sports gestures in rugby players through speed, strength and balance. **Methods.** 25 male RU players were included who repeated four gestures three times using Moticon's OpenGo sensor templates to assess seeding dynamics throughout the gestures. The data was stored in Microsoft Excel. An average of three gestures was calculated and used for statistical exploration using Wilcoxon and Friedman. **Results.** The highest mean total force (MTF) in the four gestures was located in the left foot. On the right foot, the center of pressure (COP) tended to travel faster, and the COP stroke length has been primarily larger on this foot. The line out has generally been the gesture in which the foot had the greatest MTF, and the tackle and scrum were the gestures in which the COP moved the fastest and with the longest stroke length. **Conclusion.** The line out in general was the gesture in which the foot had the highest MTF. This pressure was predominantly concentrated in the posterior and medial part of the left foot and the tackle and the pass were the gestures in which the COP traveled with more velocity and with a longer trace length, especially in the right foot.

KEYWORDS: ***Plantar Dynamics; Rugby Union; Sports Gestures; Postural Control***

INTRODUCTION

Rugby is an invasion and evasion game: once the ball is possessed by one of the teams, the main objective is to move the ball forward by kicking or carrying it into the opposite territory with the aim of scoring a try. Even though the player should aim to evade contact and pass the ball to teammates who are in space, contact is inevitable at some point in open play, which is why the athlete should know the right technique in each gesture to avoid injury (1).

To better understand the skills, it is important to know how each of them is performed and what the objective in each of them is. Four of the most important RU gestures are the pass, the tackle, the line out and the scrum. RU is the third most common contact sport in the world and being a fast-paced, collision game, this carries a high risk in injuries. (2) In the case of the amateur RU game, the studies have varied the reports involving epidemiology, ranging from 5.95/1000 player hours to 99.5/1000 player hours. Given that RU is a collision sport, the greatest number of injuries seen in this sport are caused by clashes between players, thus epidemiologically, the tackle event is the most common trigger of injury. (3) According to Tee, in the professional league of RU the estimated incidence of injuries is 81 injuries per 1000 playing hours (4).

Different studies in RU have found that there is a predominant number of injuries of a collision nature. (2-7) According to that, injury prevention is related mostly on collision trauma, and only a few studies, like Yeomans et al (5) or Kaux et al (7) talk about Non collision injuries in RU. Due to the high incidence of injuries and the variety of injury mechanisms in this sport, it is important to

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analyze the biomechanical behavior of the body in different sports-related actions/gestures, allowing the scientific community to understand them and deepen the knowledge in this area. Plantar dynamics (PD) assessment and analysis is a way of understanding the biomechanics of the foot; this way it can be understood how the forces of the foot interact during the gestures in RU.

There are several ways to evaluate PD, depending on what tool is used. Moticon's OpenGo sensor insoles are wireless sensor insoles, with an integrated internal storage, which can be used in virtually any shoe. They are made from 13 capacitive sensors, each of which measures the plantar pressure distribution and the acceleration in three dimensions in space (8). Nevertheless, it was not possible to find studies regarding plantar dynamics, center of pressure, cinematic analysis or any other study about the movement in the different gestures in RU, which also confirms the need to investigate these in order to contribute to the analysis and prevention of RU injuries. The hypothesis of the present study mentions that the plantar dynamics is modified depending on the sporting gesture being made by the RU player therefore, the present paper aims to compare plantar dynamics during four sports gestures in rugby players using physical qualities (variables) such as speed, strength and balance.

MATERIALS AND METHODS

Participants. This study is a Cross sectional study that describe the plantar dynamics in rugby players in four sports gestures (tackle, pass, scrum, line out). A total of 25 male RU players were included (mean sports age 4.87±SD 4.81 years; mean days of practice of RU 3 ±SD 0.75 days; body mass index (BMI) 26.84± SD3.75; previous injuries (3 injuries in the last year) all the players were right dominant. The sampling type was by convenience. The inclusion criteria were: being an active participant of a rugby team; having a shoe size between 36 and 44; knowing the technique to develop the different gestures evaluated and approved by the coach team. The exclusion criteria were; having an active injury that does not allow them to perform the gesture, people with degenerative musculoskeletal diseases, people under 18 or over 40 years of age, players with less than 6 months of seniority, players who had difficulties in performing any of the 4 gestures in RU. Written informed consent was obtained from all included participants in accordance with the Declaration of Helsinki and the Council for International Organizations of Medical Sciences. This study represented minimal risks for the participants.

Instruments and Variables. A characterization format was used that included name, age, sports age, height, weight, BMI, position, days of practice, active injuries at the time of the evaluation. The Moticon's OpenGo sensor insoles were used to measure the plantar dynamics during the performance of four different sports gestures. Stöggl and Martiner concluded that the insoles can measure the variables of pressure and acceleration during the tasks of walking, running and jumping with no or minimal bias (-2 to 1%), (8) which make their use valid for the study.

Studies by Stogll and Martiner and by Price were used to give validation to the Moticon's OpenGo sensor insoles in order to describe plantar dynamics in different types of analyses, such as gait, balance and postural control, emphasizing the different variables and results that can be used to understand movement in diverse scenarios, including sports sciences and sports medicine (8, 9).

The variables analyzed were total force left and right (MTFL; MTFR), a center of pressure (COP) displacement anteroposterior and mediolateral in mm left and right (COPAPL; COPAPR; COPMLL; COPMLR), the velocity of COP left and right in mm/s (VCOPL; VCOPR), COP trace length, left and right in mm. These variables were compared among the four gestures. The pass gesture was described with the gait cycle time in s, gait cadence, and the total force during the stance phase in left and right foot.

Procedure. After signing the informed consent, the players did a regular warming routine directed by their trainer. Later on, the insoles were calibrated to zero in pressure and installed for each player. They were asked to perform the four different gestures with the team. The players were also asked to do three attempts of each gesture, starting with the pass, the tackle, the line out (from the front and the back) and the scrum (one-on-one) respectively; all of these were also recorded. Finally, the templates were removed and the data were downloaded for posterior analysis. An average was calculated from the three attempts in each variable of each sport gesture; the mean data were used for the database analysis.

Statistical Analysis. The demographic data from the sample were recorded in order to characterize it and find the mean. All the data download from the insoles was placed in Microsoft Excel to filter and place in SPSS statistics software analysis, licensed by Universidad de La Sabana. The data were analyzed with the Shapiro Wilks Normality test, which showed a non-normal distribution of data, reason why, it was proceeded to use a non-parametrical test. The data were analyzed comparing each variable in each foot (right and left) using the Wilcoxon test, except in the case of COPML because the results in each foot would be inverted naturally. After this, the final average was analyzed comparing each variable in each gesture using the Friedman Test. The p value used was < 0.05.

RESULTS

The MTF is concentrated predominantly in the left foot ($p<0.05$) in each gesture. Regarding the COPAP, in each gesture the COP in the left foot tended to travel to the anterior region, in contrast to the right foot, which tended to shift to the posterior region ($p<0.05$), except in the case of the pass ($p>0.05$). In the case of the COPV, the velocity was similar in each foot ($p>0.05$), only in the case of the pass the COP tended to travel faster in the right foot. Regarding the COPTL, the results show that the trace length of the COP is not different between feet ($P>0.005$), and just like in the pass, the trace length was longer in the right foot ($P<0.05$) Table 1.

Comparing five gestures MTFL and MTFR, the gestures that discharged the most force were the frontal base and backwards base line out ($P<0.005$) when compared each of the other gestures, and the gesture that discharged the least force was the tackle ($P<0.005$) Figure 1.

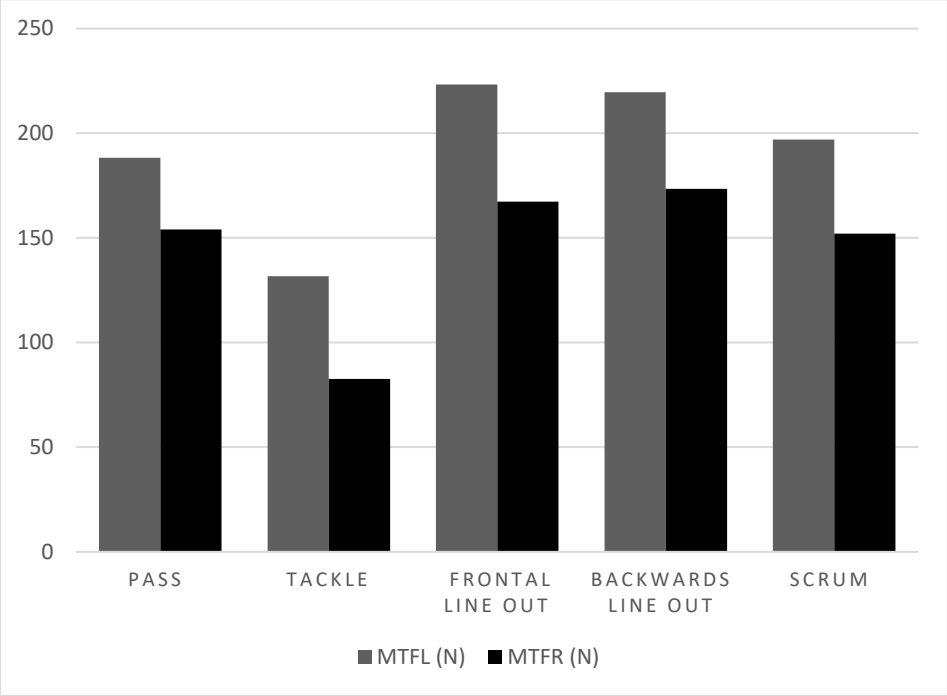

Figure 1. Difference between Gesture and Leg Dominance Mean Total Force (N). *MTFL: mean total force left foot *MTFR: mean total force right foot

Regarding the COPAPL, the gestures that shifted their COP most to the anterior part of the foot were the tackle and the scrum ($P<0.005$), and the gestures that shifted their COP to the most posterior part of the foot were the frontal base and backwards base line out ($P<0.005$) compared with the other gestures. The results of the COPAPR show that the frontal base and backwards base line out are the gestures in which the COP shifts most to the posterior part of the foot when compared to the other gestures ($P<0.005$). In the case of the COPMLL, the results show that all the gestures tended to shift their COP most to the medial part of the foot, with the exception of the pass ($P<0.005$). Regarding the COPMLR, there was no significant difference between any of the gestures.

The results of the COPVL show that the gesture in which the COP shifted with more velocity was the tackle, when compared to the other gestures (P<0.005) Figure 2. In the case of the COPVR, the results show that the gestures where the COP shifted with more velocity were the tackle and the pass (P<0.005) Table 2. The COPTLL, the gestures in which the COP traced a longer line were the tackle, the pass and the scrum (P<0.05) Figure 3. And finally, in the case of the COPTLR, the COP traced a longer line in the tackle, the backwards base line out and the scrum.

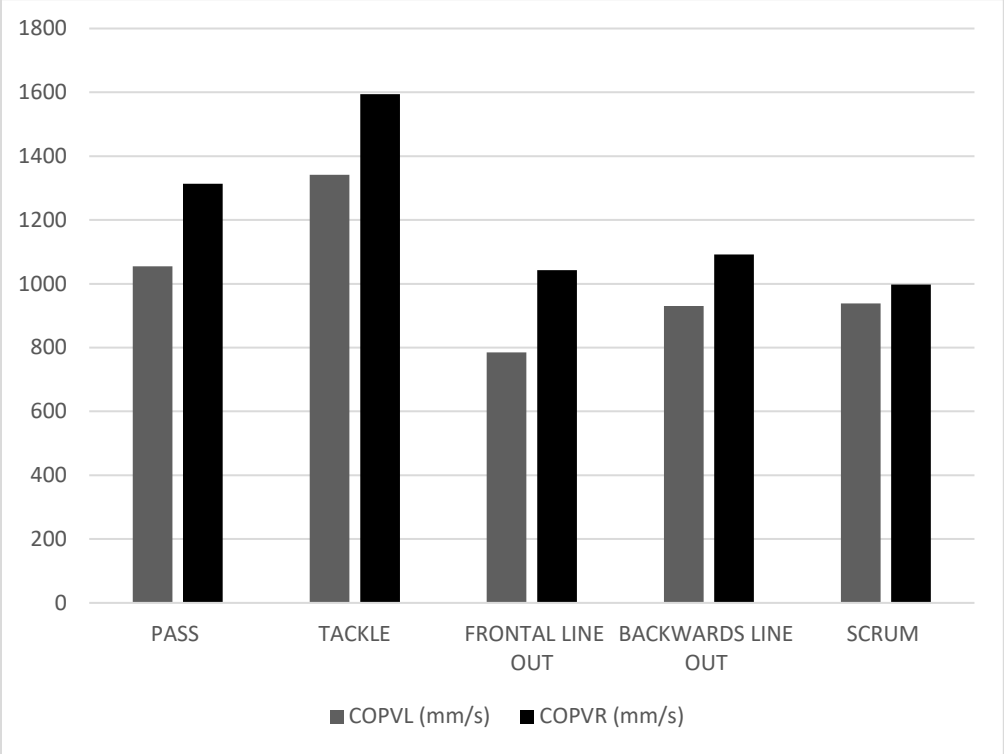

Figure 2. Difference between Gesture and Leg Dominance Center of Pressure Velocity (mm/s). * COPVL: center of pressure velocity left foot. * COPVR: center of pressure velocity right foot

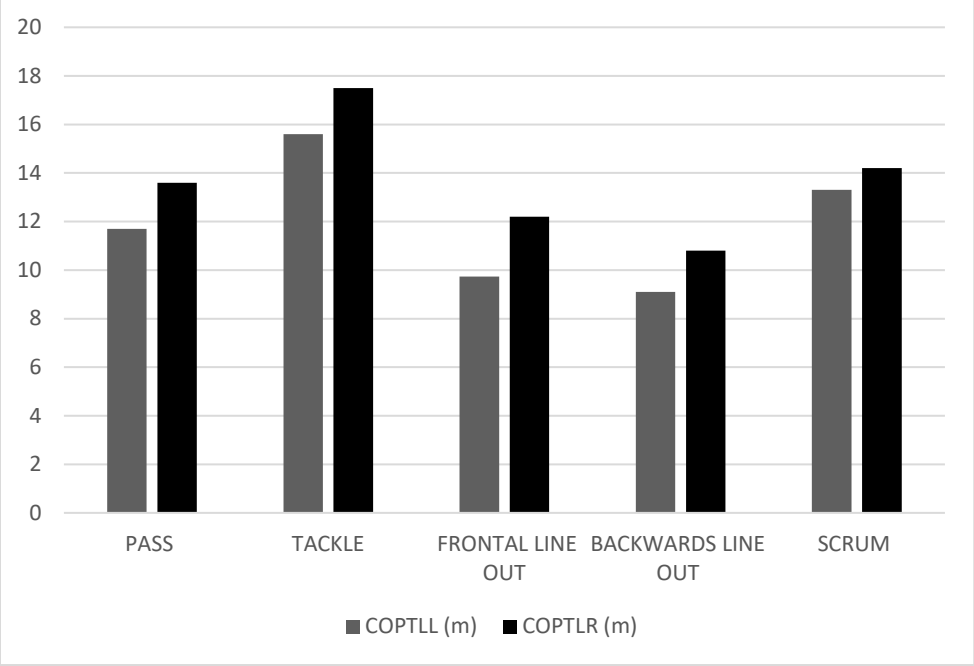

Figure 3. Difference between Gesture and Leg Dominance Center of Pressure trace length (mm). * COPTLL: center of pressure trace length left foot. *COPTLR: center of pressure trace length right foot

Table 1. Difference between Right and Left Leg

Variable	Pass (P Median (IL/SL)	Dif (P Value)	Tackle (T Median (IL/SL)	Dif (P Value)	Frontal Line Out (LF) Median (IL/SL)	Dif (P Value)	Backwards Line Out (LB) Median (IL/SL)	Dif (P Value)	Scrum (S) Median (IL/SL)	Dif (P Value)
MTFL (N)	188.3 (167.7/216)	34.3 (0.001)	131.7 (114.6/169.8)	49.1 (0.000)	223.3 (197.6/248.4)	56 (0.000)	219.7 (202.8/254.9)	46.2 (0.001)	197 (171.2/220.7)	45 (0.000)
MTFR (N)	154 (124.4/159.3)	34.3 (0.001)	82.6 (74.3/106.7)		167.3 (146.9/178.2)	56 (0.000)	173.5 (149/186.7)	46.2 (0.001)	152 (123.9/158.1)	45 (0.000)
COPAPL (mm)	5.73 (-10.2/10.05)	6.47 (0.55)	9.7 (6.7/25.1)	5.6 (0.001)	-3.5 (-44.9/121.4)	22.4 (0.000)	-7.07 (-15.9/3.3)	21.03 (0.006)	13.3 (4.7/25.3)	9.8 (0.033)
COPAPR (mm)	-12.2 (-21.3/-0.5)	6.47 (0.55)	-4.1 (-21.3/-0.3)	5.6 (0.001)	-25.9 (-40.5/-15.5)	22.4 (0.000)	-28.1 (-37.3/-14.4)	21.03 (0.006)	3.5 (-14.3/27.5)	9.8 (0.033)
COPMLL (mm)	0.9 (-1.91/2.82)	0.17 (0.230)	3 (0.7/5.7)	1.4 (0.089)	2.6 (0.41/5.04)	2.34 (0.026)	3.4 (-0.2/4.6)	2.47 (0.055)	5.16 (-1.5/6.8)	4.36 (0.006)
COPMLR (mm)	-1.1 (-3.81/0.8)	0.17 (0.230)	-1.6 (-3.8/1.1)	1.4 (0.089)	-0.26 (-3.3/0.7)	2.34 (0.026)	-0.93 (-3.6/1.3)	2.47 (0.055)	0.8 (-4.04/1.6)	4.36 (0.006)
COPVL (mm/s)	1054.3 (963.7/1400.1)	258.9 (0.006)	1341.1 (1228/1728.3)	253.6 (0.523)	784.7 (692/1082.3)	258.3 (0.068)	930.1 (737.3/1164.3)	161.8 (0.114)	938.4 (825.3/1289.9)	59 (0.784)
COPVR (mm/s)	1313.2 (1189.3/2214.2)	258.9 (0.006)	1594.7 (1412.5/1952.7)	253.6 (0.523)	1043 (926.9/1275.9)	258.3 (0.068)	1091.9 (241.5/3846.1)	161.8 (0.114)	997.9 (896.9/1298.4)	59 (0.784)
COPTLL (m)	11.7 (10.2/15.2)	1.9 (0.004)	15.6 (13.2-20.4)	1.9 (0.412)	9.74 (8.5/13.1)	2.49 (0.107)	9.1 (8.4/14.2)	1.7 (0.114)	13.3 (12.2/20.2)	0.9 (0.670)
COPTLR (m)	13.6 (12.6/17.4)	1.9 (0.004)	17.5 (15.7/21.6)	1.9 (0.412)	12.2 (10.8/15.4)	2.49 (0.107)	10.8 (10.6/17.3)	1.7 (0.114)	14.2 (13.5/21.5)	0.9 (0.670)
MTFSPL	307.8 (274.3/341.1)	27.9 (0.027)								
MTFSPR	279.9 (252.4/307.4)	27.9 (0.027)								

***MTFL: mean total force left foot, *MTFR: mean total force right foot, *COPAPL: center of pressure anterior-posterior left foot. *COPAPR: center of pressure anterior-posterior right foot, *COPMLL: center of pressure medial-lateral left foot, *COPMLR: center of pressure medial-lateral right foot, *COPVL: center of pressure velocity left foot, *COPVR: center of pressure velocity right foot. *COPTTL: center of pressure trace length left foot, *COPTLR: center of pressure trace length right foot, *MTFSPL: mean total force during stance phase left foot, *MTFSPR: mean total force during stance phase right foot.**

DISCUSSION

This study aimed to identify the foot dynamics during four sports gestures in RU players through physical qualities such as speed, balance and strength. The results show that there is significant asymmetry in the COP variables and powerful differences in the pressures applied on each foot ($P<0.005$) during the performance of the gestures. Figen et al., in their study about asymmetry in plantar pressure, stated that "Unbalanced distribution of plantar forces may be a cause of stress fractures on the metatarsal heads." (10) This knowledge leads us to think that undistributed plantar forces may cause stress in the feet, which may cause different kinds of injuries. Wafai et al., in their study on the distribution of forces in the feet, also agree with this statement, arguing that "The site of injury is often related to the plantar forces and the distribution of these forces in each foot." (11).

The highest MTF in the four gestures was found in the left foot. This pressure is localized predominantly in the anterior and medial part of the foot, and with these results it can be concluded that the left foot – and specifically the anterior and medial part – is the most overloaded spot of the feet during the four sports gestures. In the case of the right foot, the COP tended to travel predominantly to the posterior and medial part of the foot. Regarding the COP trace length and velocity, there was no significant difference between the feet ($P<0.005$). The overload and the asymmetry in the dynamics of each foot could also explain why the lower limb is the most affected part of the body (30-55% of injuries). (7) In addition, the continuous increase in speed and force over the years in the rugby game (1) could contribute to the incidence of injuries of this nature.

Table 2. Difference between Gestures

Gesture vs Gesture	MTFL DIF (P Value)	MTFR DIF (P Value)	COPAPL DIF (P Value)	COPAPR DIF (P Value)	COPMLL DIF (P Value)	COPMLR DIF (P Value)	COPVL DIF (P Value)	COPVR DIFE (P Value)	COPTLL DIF (P Value)	COPTLR DIF (P Value)
Pass-tackle	56.6 (0.000)	71.4 (0.000)	3.97 (0.001)	8.1 (0.855)	2.1 (0.003)	*	286.8 (0.012)	281.5 (0.201)	3.9 (0.11)	3.9 (0.033)
Pass-frontal L.O.	35 (0.000)	13.3 (0.012)	2.23 (0.738)	13.7 (0.005)	1.7(0.003)	*	269.6 (0.001)	270.2 (0.002)	1.96 (0.094)	1.4(0.107)
Pass-backwards L.O.	31.4 (0.002)	19.5 (0.013)	1.34 (0.378)	15.9 (0.031)	2.5 (0.114)	*	124.2 (0.013)	221.3 (0.031)	2.6 (0.059)	2.8 (0.378)
Pass-scrum	8.7 (0.181)	2 (0.948)	7.57 (0.014)	8.7(0.048)	4.26 (0.045)	*	115.4 (0.114)	315.3 (0.003)	1.6 (0.052)	0.6 (0.354)
Tackle - frontal L.O.	91.6 (0.000)	84.7 (0.000)	6.2(0.006)	21.8 (0.004)	0.4(0.784)	*	556.4 (0.000)	551.7 (0.001)	5.86 (0.001)	5.3 (0.000)
Tackle - backwards L.O.	88 (0.000)	90.9 (0.000)	2.63 (0.000)	24 (0.014)	0.4 (0.301)	*	411 (0.000)	502.8 (0.021)	6.6 (0.002)	6.7(0.316)
Tackle - scrum	65.3 (0.000)	69.4 (0.000)	3.6 (0.627)	0.6 (0.104)	2.16 (0.761)	*	402.2 (0.003)	596.8 (0.002)	2.3 (0.648)	3.3 (0.677)
Frontal L.O.-Backwards L.O.	3.6 (0.867)	6.2 (0.988)	3.57 (0.224)	2.2 (0.429)	0.8 (0.503)	*	145.4 (0.236)	48.9 (0.301)	0.64 (0.584)	1.4 (1)
Frontal L.O.-Scrum	26.3 (0.001)	15.3 (0.018)	9.8 (0.019)	22.4 (0.000)	2.56 (0.605)	*	154.2 (0.052)	45.1 (0.301)	3.56 (0.002)	2(0.005)
Backwards L.O.-Scrum	22.7 (0.002)	21.5 (0.008)	6.23 (0.000)	24.6 (0.000)	1.76 (0.171)	*	8.8(0.023)	94 (0.248)	4.2 (0.000)	3.4 (0.012)

***There was no significant difference between any of the gestures. *MTFL: mean total force left foot, *MTFR: mean total force right foot, *COPAPL: center of pressure anterior-posterior left foot. *COPAPR: center of pressure anterior-posterior right foot, *COPMLL: center of pressure medial-lateral left foot, *COPMLR: center of pressure medial-lateral right foot, *COPVL: center of pressure velocity left foot, *COPVR: center of pressure velocity right foot. *COPTTL: center of pressure trace length left foot, *COPTLR: center of pressure trace length right foot, *MTFSPL: mean total force during stance phase left foot, *MTFSPR: mean total force during stance phase right foot.**

The line out, in general, was the gesture in which the foot had the highest MTF. This pressure was predominantly concentrated in the posterior and medial part of the right foot, suggesting to conclude that in this population the most overloaded spot on the plantar surface was located in the right foot, specifically in the posterior and medial zone during the two line outs.

The tackle and the pass were the gestures in which the COP traveled with more velocity and with a longer trace length. This could mean that these two gestures are the ones with the most instability. This is also mentioned in the study by Alfonso-Mora et al., in which they noted that variables like displacement and velocity tend to mean that there is more instability at the time of the gestures (12). This knowledge could explain why the tackle, and specifically the player doing the gesture, is accredited with being the most injurious of the gestures in the sport (3, 5, 13, 14). In another study by Alfonso-Mora et al., the authors point out that it is important to measure the plantar dynamics in the field where the athletes perform their activities, since the ground where they move could change the form in which plantar dynamics distribute their variables (12).

Hawrlyak et al. reported that the pressure concentrated in the medial part of the foot during running could increase the susceptibility of the fourth and fifth metatarsal fractures (15). Furthermore, Uzun et al. concluded that repetitive eversion stress in the feet could be linked to fractures (16). In our study, during the running phase of the pass, the pressure was concentrated in the medial part of the foot: this gesture could expose the players to suffer these kinds of fractures.

The study found that right-dominant players put more pressure on the left foot in the pass, tackle, lineout and scrum gestures in amateur rugby players, On the other hand, the right foot is more unstable, because the speed and displacement of the pressure center is greater in this lower limb. The gesture with the greatest release of pressure on the foot was the lineout, possibly because the player must carry a partner.

CONCLUSION

As a conclusion, the results show there is significant asymmetry in the COP variables and powerful differences in the pressures applied on each foot ($P<0.005$). The highest MTF in the four gestures was found in the left foot. In addition, this pressure is localized predominantly in the anterior and medial part of the foot. In the right

foot, the COP tended to travel predominantly to the posterior and medial part of the foot, and the velocity and trace length of the COP was mainly higher in this foot. The line out in general was the gesture in which the foot had the highest MTF. This pressure was predominantly concentrated in the posterior and medial part of the left foot and the tackle and the pass were the gestures in which the COP traveled with more velocity and with a longer trace length, especially in the right foot.

The limitation of the study was the sample size. In following studies, more people should be included in the evaluations. It is recommended to deepen the knowledge of the plantar dynamics in rugby. Currently, in the literature there is not enough evidence to have a sure understanding of how the plantar dynamics interact with each other in the feet of the players. This study was made with a population of amateur rugby players, and it is suggested that studies like this should be made in professional rugby teams and with a bigger population so the results have more impact in the understanding of plantar dynamics in RU.

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APPLICABLE REMARKS

The results of this research have an impact on the sport gesture considerations of rugby players and the prevention of rugby-related injuries.

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CONFLICT OF INTEREST

All authors of this work declare not to have a conflict of interest.

ETHICS DECLARATIONS

Research involving human participant: All procedures performed in this study were in accordance with the ethical standards of the Universidad de La Sabana research committee, law 8430 and with the Helsinki declaration. The risk of the research was minimal and voluntary participation was a guarantee.

INFORMED CONSENT

Informed consent was obtained from all participants in the study, this documentation is saved in Universidad de La Sabana.

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