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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 and 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.** Twenty-five 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 four gestures' highest mean total force (MTF) was on the left foot. On the right foot, the center of pressure (COP) tended to travel faster, and the COP stroke length was 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 parts 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 to score a try. Even though the player should aim to evade contact and pass the ball to teammates 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 their objective is. Four of the most important RU gestures are the pass, the tackle, the line out, and the scrum. RU is the world's third most common contact sport, and being a fast-paced, collision game, this carries a high risk of 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 most significant number of injuries seen in this sport are caused by clashes between players, and 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 per 1000 playing hours (4).

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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 to 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 analyze the biomechanical behavior of the body in different sports-related actions/gestures, allowing the scientific community to understand them and deepen their knowledge in this area. Plantar dynamics (PD) assessment and analysis is a way of understanding the foot biomechanics; 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 the tool used. Motion's OpenGo sensor insoles are wireless with 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, the 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 to contribute to the analysis and prevention of RU injuries. The hypothesis of the present study mentions that the plantar dynamics are modified depending on the sporting gesture being made by the RU player. Therefore, the present paper compares plantar dynamics during four sports gestures in rugby players using physical qualities (variables) such as speed, strength, and balance.

MATERIALS AND METHODS

Participants. This cross-sectional study describes 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 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 coaching 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 under 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, and 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 could 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 makes 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 the left and right foot.

Procedure. After signing the informed consent, the players did a regular warming routine directed by their trainer. Later, the insoles were calibrated to zero 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 sample's demographic data were recorded to characterize it and find the mean. All the data downloaded from the insoles were placed in Microsoft Excel to filter and 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, which is why it used a non-parametrical test. The data were analyzed by comparing each foot variable (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 by comparing each gesture variable using the Friedman Test. The p-value used was < 0.05.

RESULTS

The MTF is concentrated predominantly in each gesture's left foot ($p<0.05$). 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 past, 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 backward baseline out ($P<0.005$) when compared each of the other gestures, and the gesture that discharged the minor force was the tackle ($P<0.005$) Figure 1.

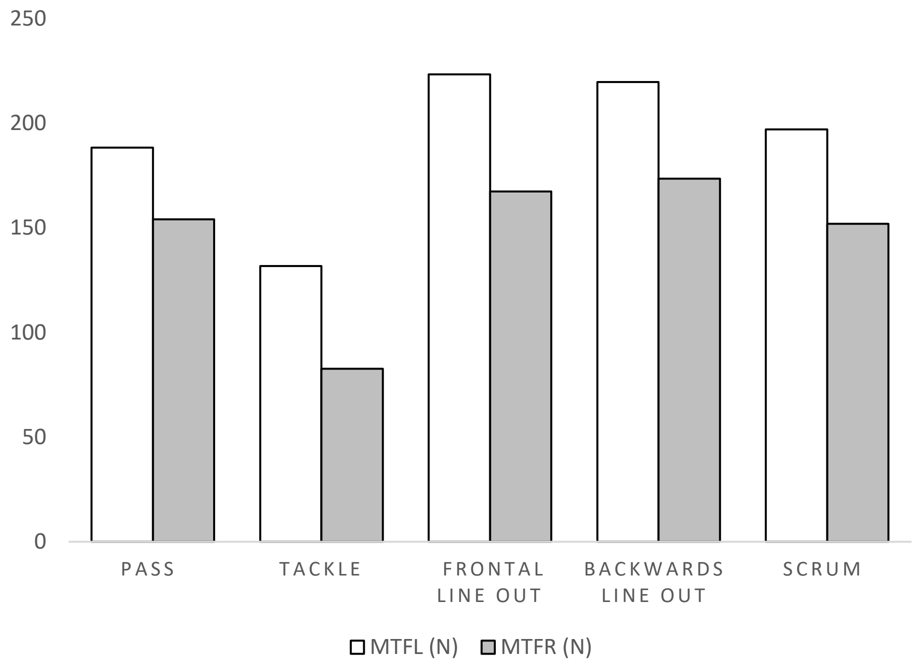

Figure 1. Difference between Gesture and Leg Dominance Mean Total Force (N). *MTFL: mean total force left foot *MTFR: mean total force right foot

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 backward baseline out ($P<0.005$) compared with the other gestures. The results of the COPAPR show that the frontal base and backward baseline 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, except the pass ($P<0.005$). Regarding the COPMLR, there was no significant difference between the gestures.

The results of the COPVL show that the gesture in which the COP shifted with more velocity was the tackle 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. In 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. Moreover, finally, in the case of the COPTLR, the COP traced a longer line in the tackle, the backward baseline out, and the scrum.

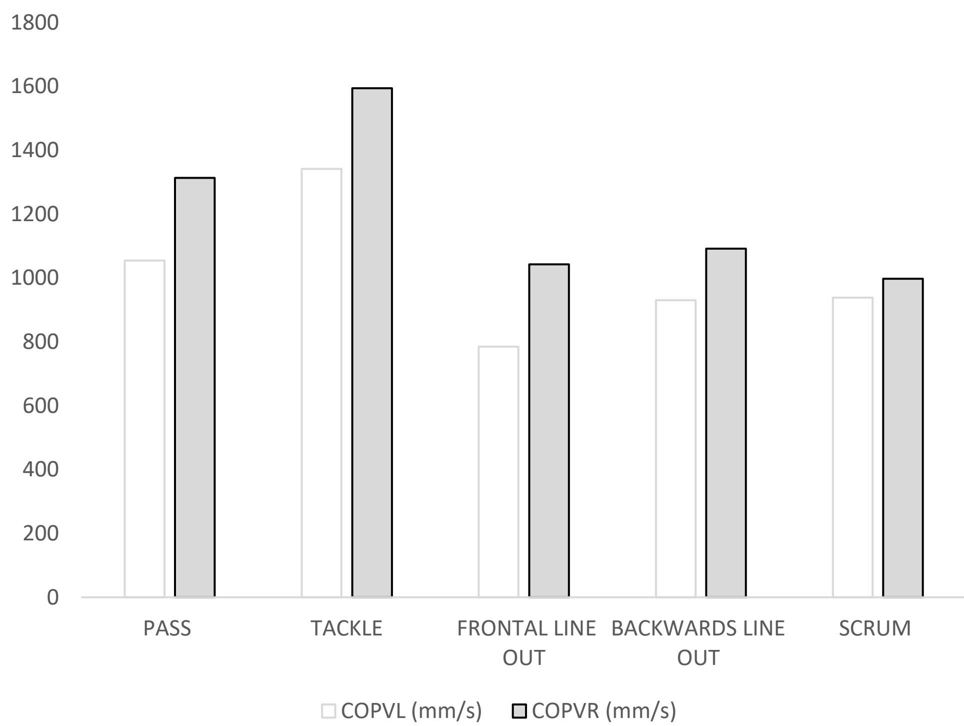

Figure 2. Difference between Gesture and Leg Dominance Center of Pressure Velocity (mm/s). * COPVL: center of pressure velocity left foot. * COPVR: center of pressure velocity right foot

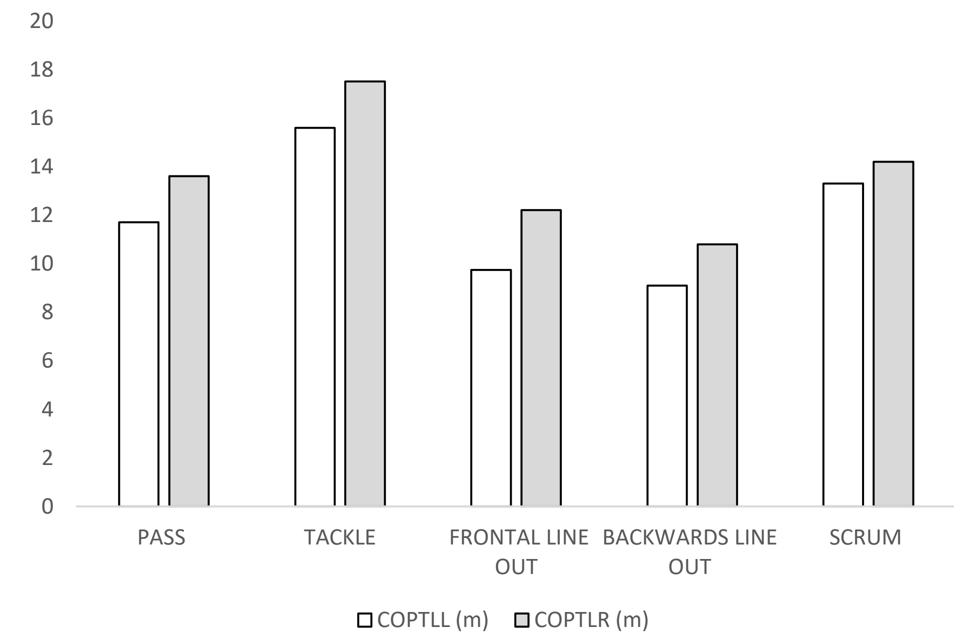

Figure 3. Difference between Gesture and Leg Dominance Center of Pressure trace length (mm). * COPTLL: center of pressure trace length left foot. *COPTLR: center of pressure trace length right foot

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 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 –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 parts 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.

The line out, in general, was the gesture in which the foot had the highest MTF. This pressure was predominantly concentrated in the right foot’s posterior and medial part, suggesting 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.

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 LO.	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 LO.	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 tackle and the pass were the gestures in which the COP traveled with more velocity and a longer trace length. It could mean that these two gestures have the most instability. It is also mentioned in the study by Alfonso-Mora et al., in which they noted that variables like displacement and velocity tend to mean more instability at the time of the gestures (12). This knowledge could explain why the tackle, specifically the player making the gesture, is 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 past, tackle, line-out, 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 are greater in this lower limb. The gesture with the greatest pressure release on foot was the line-out, possibly because the player must carry a partner.

CONCLUSION

In conclusion, the results show 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 parts of the foot. In the right foot, the COP tended to travel predominantly to the posterior and medial parts 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 a longer trace length, especially in the right foot.

The limitation of the study was the sample size. In the following studies, more people should be included in the evaluations. It is recommended to deepen the knowledge of the plantar dynamics in rugby. Currently, there is not enough evidence in the literature to understand how the plantar dynamics interact with each other at 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 understanding plantar dynamics in RU.

APPLICABLE REMARKS

- The results of this research impact the sporting gesture considerations of rugby players and the prevention of rugby-related injuries.

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AUTHORS' CONTRIBUTION

Study concept and design: M.L.A.M., C.R.R., L.M.H.Y. Acquisition of data: M.L.A.M., C.R.R., L.M.H.Y. Analysis and interpretation of data: M.L.A.M., C.R.R., L.M.H.Y. Drafting of the manuscript: M.L.A.M., C.R.R., L.M.H.Y. Critical revision of the manuscript for important intellectual content: M.L.A.M., C.R.R., L.M.H.Y. Statistical analysis: M.L.A.M., C.R.R., L.M.H.Y. Administrative, technical, and material support: M.L.A.M., C.R.R., L.M.H.Y. Study supervision: M.L.A.M., C.R.R., L.M.H.Y.

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CONFLICT OF INTEREST

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

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