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Postural evaluation and risk of musculoskeletal injuries in professional male rugby players: a proof-of-principle study

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Abstract

Background: Posture in ideal balance allows the maximum effectiveness of a gesture in absence of pain. Rugby is a sport characterized by muscle-tendon structures injuries due to trauma and an adequate posture might have a role in their prevention. Aim of this proof-of-principle study was to investigate if sports activity might cause postural changes in National League rugby players and whether it correlates with an increased risk of injuries.

Methods: Male rugby players from a National League were included in the study. The athletes underwent a postural questionnaire, an analysis of plantar support (3D-PodoScanalyzer) and a postural-evaluation (Formetric4D). The tests were performed at T0 (on-season), T1 (off-season) and T2 (pre-season).

Results: Twenty-six male rugby players, mean aged 22.5 years old, were included. The analysis of plantar support showed statistically significant variability in 6 values: left Arch index (p=0.004), right Staheli index (p=0.042), midfoot symmetry (p=0.030), isthmus symmetry (p=0.048), arch length symmetry (p=0.027), height of the left plantar arch (p=0.009). The postural analysis showed statistically significant variability in only two values: rotation of the pelvis (p=0.013) and kyphotic angle (p=0.050).

Conclusions: Taken together, our findings data describe a cavity in the left foot during the intense stages of the championship in which injuries to the left lower limb also prevail. The study also shows that the training conducted by the athletes examined improves the pelvic rotation and kyphotic angle values.

Keywords: Rugby; Postural Evaluation; Posture; Injury; Rehabilitation.

Introduction

Rugby is the most played contact sport in the world. World Rugby, the international board that regulates it, estimates that there are over 12 million players for the rugby union code alone. It is a sport that involves considerable physical effort and violent impacts, as well as a constant aerobic commitment. Unlike most sports, especially at a high level, rugby shows an unusual heterogeneity of physiques. This difference finds his motivation in the need for a team to simultaneously have on the field athletes that perform very different athletic gestures, from maximum acceleration to lifting a weight, from tackling an opponent to kicking the ball. The great physical and competitive de-mand of rugby has led to a high number of injuries.[1,2] The probability of injury has been linked to several factors: age, sex, BMI, clinical history, player role, level of play.[3] Although rugby is a contact sport, most injuries affect the muscle-tendon structures and ligaments of the lower limbs through indirect trauma; this underlines the importance and the need to "build" a body suitable to withstand multiple stresses that it must bear during every training and every match.[4,5] Starting from this assumption, it is necessary to investigate possible factors favoring indirect traumas (such as postural changes) that can be closely related to sports activity and avoided. Rugby players undergo a great physical and competitive demand that may cause many injuries; the relatively recent increase in the number of players has led to the production of many studies that try to analyze the mechanisms, incidence, and risk factors of injuries, but the literature is inconsistent and not unanimous.[1,2] The incidence of injuries among professional rugby players seems to vary between 27 and 218 per 1000 hours of match and between 2 and 6 per 1000 hours of training in the studies analyzed; for amateur rugby players the incidence drops to about 47 per 1000 match hours.[2,4-10] Although rugby is a contact sport, most injuries affect the muscle-tendon structures and ligaments of the lower limbs through indirect trauma.[2,4,5] Williams et al., in 2017, published an interesting article that demonstrates the correlation between games played in the last 12 months, games played in the last month and injury predisposition: players who have played less than 15 times or more than 35 times in the last year present an increased risk compared to teammates.[5]

Posture is the position the various parts of the body take compared to each other and to space, both in static and dynamic conditions. It is regulated by involuntary contractions of the antigravity skeletal muscles, through observable responses both in orthostasis and in the dynamic gesture, with the aim of protecting the support structures of the body from injuries or deformities.[11,12] The posture in ideal balance allows for maximum effectiveness of a gesture in absence of pain and with maximum energy savings. The head should be erect in a well-balanced position; the spine has three physiological curves, cervical lordosis (about 15°), dorsal kyphosis (10°-45°) and lumbar lordosis (40°-60°), which provide support and resistance to longitudinal pressures;[11] the hips, knees, ankles and feet have an ideal alignment for weight support; the plantar support is distributed over the entire surface of the foot sole and is associated with a normal, non-painful medial longitudinal plantar arch and the hindfoot aligned to the leg.[11,12] Pain is the dominant manifestation in cases of symptomatic postural changes, which is often alleviated by physical activity and worsened by sedentary activities such as working at a desk: this shows that a sedentary lifestyle has an important impact on posture.[11] Recently, new clinical tests and new instrumental investigations have been experimented with the aim of studying the individual's posture more thoroughly and trying to correct the underlying causes of alterations. Numerous anamnestic-clinical protocols have been developed including a holistic or segmental approach, but the diagnosis of postural dysfunction also requires specific instrumental investigations, to identify its nature and extent.[14-20] Correct posture and its control are fundamental aspects, especially in sport. Every sporting activity is influential on the musculoskeletal system and the effects of this phenomenon can be amplified if the technical-athletic gesture is performed with an incorrect posture.[11,12] Although it is not clear how the quality and quantity of sporting activity affect posture, it is evident in literature that some structural alterations of the musculoskeletal system are prevalent in certain categories of athletes: runners, volleyball, tennis, football, and basketball players, for example, have a higher pronated foot percentage, while supinated foot seems to prevail among handball players.[21-25] On the other hand, it has been hypothesized that some types of posture may favor certain disciplines: hyper-lordosis seems to improve performance in American football, Australian football and soccer.[26,27] The prevention of injuries through the identification of risk factors plays a fundamental role in the management of an athlete. The risk of injury is closely correlated with well-known modifiable and non-modifiable factors such as age, the Body Mass Index (BMI), the occurrence of injuries in the last 12 months, muscle strength, the quality of the athletic gesture.[28,29] Postural assessment must be quantitative, objective, and precise to be predictive of an injury. Videorasterstereography (Formetric4D) allows to study and monitor postural deformities of the spine over time: by projecting parallel lines of light on the patient's back, the device recognizes any distortions and asymmetries and recreates a three-dimensional map of the posture.[30-34] The 3D PodoScanalyzer is a tool that analyzes static plantar support thanks to a scan capable of providing information on the shape of the foot. It can measure and quantify numerous parameters, such as the length of the foot, the width of the forefoot, the isthmus and the hindfoot, the measurements of the arch, the plantar angles, and the symmetry indices between the two feet.[35]

Therefore, aim of this proof-of-principle study was to investigate if sports activity might cause postural changes in professional male rugby players and whether it could correlate with an increased risk of injury.

Methods

Participants

Healthy male rugby players from the national league were considered for this study. The inclusion criteria were: male rugby players, between 18 and 42 years old; players of the national second or third league (Serie A or Serie B); no significant injuries in the past 3 months; two workouts per week including stretching and aerobic warm up, in-dividual and skills drills, one training match and two gym sessions per week. The exclusion criteria were: recent injuries; less than 3 workouts per week;

players of international or amateur level. No player had undergone major surgery in the previous year or suffers from relevant underlying diseases.

The analysis was conducted at the Physical and Rehabilitative Medicine outpatient's clinic of the Sapienza University of Rome - Umberto I University Hospital in Rome, between January 2020 and October 2020. This study protocol was developed in accordance with the STROBE guidelines and was approved by the Ethics and Experimental Research Committee of Sapienza University, Rome, Italy (Prot. N° Rif. 6221, Prot. 0104/2021). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national re-search committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Once having informed participants about the aim of the study, informed consent was obtained from all individual participants enrolled.

A questionnaire with objective and subjective questions, an evaluation of plantar support using 3D PodoScanalyzer and a postural evaluation using Formetric4D were ad-ministered in the same order.

Questionnaire on the athlete's state of health

The questionnaire investigates the athlete's state of health in the previous 24 months, including questions on the possible presence of known morpho-structural alterations. Players were asked to report major muscle injuries and fractures, the onset of back pain, coxalgia, knee pain or foot pain during sports or daily living activities, vision, hearing or stomato-gnathological problems, use of insoles, bite, or eyeglasses.

3D PodoScanalyzer

The 3D PodoScanalyzer (Diasu by Sani Corporate, Rome, Italy) is a tool that analyzes static plantar support thanks to a scan capable of providing information on the shape of the foot. It provided data on the support and characteristics of the foot arch. Specifically, we analyzed:

- Arch Index (AI), obtained by dividing the midfoot area by the entire foot area.
- Staheli Index, obtained by dividing the midfoot width by the hindfoot width.
- Podalic Symmetry Index: the difference in length between the two feet; it is calculated as the difference in length between the two feet divided by the sum of the length of the two feet, all multiplied by 100.
- Metatarsal Symmetry Index: the difference in width between the right and left forefoot; it is calculated as the difference in forefoot amplitude between the two feet divided by the sum of the metatarsal amplitude of the two feet, all multiplied by 100.
- Isthmus Symmetry Index: the difference in width between the isthmus of the two feet; it is calculated as the difference in the width of the isthmus of the two feet divided by the sum of the width of the isthmus of the two feet, all multiplied by 100.
- Plantar arch Symmetry Index: the height difference between the two arches; it is calculated as the difference in arch height between the two feet divided by the sum of the height of the vault of the two feet, all multiplied by 100.
- Hindfoot Symmetry Index: the difference in transverse width between the two heels; it is calculated as the difference in the width of the heel between the two feet divided by the sum of the transverse width of the heel of the two feet, all multiplied by 100.
- Calcaneal Length Symmetry Index: the difference in longitudinal width be-tween the two heels; it is calculated as the difference in the longitudinal width of the heel between the two feet divided by the sum of the longitudinal width of the heel of the two feet, all multiplied by 100.

- Calcaneal Semicircle Symmetry Index: the difference between the values of the external perimeters of the heel between the two feet; it is calculated as the difference of the external perimeter of the heel between the two feet divided by the sum of the external perimeter of the heel of the two feet, all multiplied by 100.

- Plantar Angle Symmetry Index: the difference between the values of the longitudinal plantar angles between the two feet; it is calculated as the difference in the longitudinal plantar angle between the two feet divided by the sum of the longitudinal plantar angle of the two feet, all multiplied by 100.

- Tarsal Epicenter Index: the difference between the values of the intersections of the calcaneal cuboids between the two feet; it is calculated as the difference of the intersection of the calcaneal cuboid between the two feet divided by the sum of the intersection of the calcaneal cuboid of the two feet, all multiplied by 100.

- Medial Subtalar Variation: the difference between the medial subtalar angles of the two feet.

- Lateral subtalar variation: the difference between the lateral subtalar angles of the two feet.

- Left and right Plantar Arch Index: the height of the arch measured for each foot.

- Left and right longitudinal plantar angle Index: the angle formed by the two external tangents to each foot.

- The Postural Biomechanical Index (PBI) is generated by the 3D PodoScanalyzer software, considering all the measured data.

The patient stands on the platform in the posture that he considers to be the most nat-ural, with the knees extended, the upper limbs relaxed, the gaze to the horizon, feet in most comfortable position in a well-lit room.[35]

All tests were conducted in the same room and in the same lighting conditions (Figure 1).

Formetric4D

The Formetric (DIERS International GmbH, Schlangenbad, Germany) is a radiation-free analysis system used in assessing spinal posture and pelvic position. It has been reported to have a high correlation with radiographic assessments of the anatomy of spine and pelvis, as well as high accuracy and reliability in static and dynamic conditions.[30-34] It uses the principle of videorastereography, projecting horizontal bands of halogen light onto the player's back to reconstruct a three-dimensional postural image, providing objective postural data (Figure 2). The following parameters were considered:

- Anteroposterior and lateral flexion of the spine
- Pelvic tilt and rotation.
- Torsion of the hemi-pelvis.
- Cervical and lumbar arrow, which measures if the spine is aligned to the in-tergluteal cleft.
- Kyphotic and lordotic angle.
- Superficial rotation of the spine.
- Lateral deviation of the spinous processes.

The tests were carried out in three distinct moments of the season: on-season (T0), off-season (T1) and pre-season (T2). The on-season tests (from January 27 to February 7, 2020) were carried out immediately after the phase of the season in which the players, after the Christmas break, played three games in three consecutive Sundays. We chose to carry out the analysis in January because players have a higher risk of injuries, as documented in the literature, due to the high number of games after a period of absence from the playing field.[6,36,37]

The off-season tests (from 22 June to 4 September 2020) were carried out in the summer when the players do not play rugby but keep training in the same facility in mild aerobic workouts that do not involve physical contact and sport-specific gestures; they all carried out the same fitness program.

The pre-season tests (from 5 to 9 October 2020) were carried out at the end of the pre-season training and close to the first friendly matches of the season, a period in which players should be healthy, aerobically, and anaerobically trained and ready for the physical efforts they will face in the following months. Muscle performance should be optimal at this moment, as the player has not yet suffered the influences of fatigue and injuries. The athletes, however, in the month of October presented a different physical condition: 12 of these had played a friendly match in the previous 7 days; 10 had only done full training; 4 had partially suspended sporting activities for family or work reasons. It was therefore possible to analyze whether competitive activity, training and rest contribute differently to posture.

Statistical analysis

The statistical analysis was conducted using the IBM SPSS version 25; the data were represented in terms of median and range of representation (minimum-maximum). The comparison between the spinal and plantar postural variables in the various evaluation times (T0, T1 and T2) was carried out through a Friedmann analysis for repeated measurements with subsequent post-hoc analysis; significance was defined with a p value <0.05. For the sample size calculation, the G * Power Version 3.1.9.2 program was used. The difference within group with respect to the kyphotic angle was considered a primary parameter for postural outcome. The following values were considered for the kyphotic angle: mean1 (kyphotic angle) = 46.86° (8.2), mean2 (kyphotic angle) = 40.08 (8); for a type 1 error (a) of 5%, a type 2 error (b) of 5%, and a power level of 0.95, the required sample size was 17.

Results

We included 26 male rugby players, mean aged 22.5 years old (range 18-29 years old), who participate in the Second and Third national league (Serie A and Serie B).

The questionnaire showed rather uniform data: only two athletes reported major fractures during their sports career (two tibial malleolus fractures); five athletes reported muscle injuries to the knee flexors (4 left, 1 right) and two others reported symptoms attributable to groin pain in the 24 months prior to the tests (all athletes recovered at least 3 months before the start of the study); twenty-two athletes reported back pain (mainly cervical and lumbar) during intense physical activity; nine athletes reported knee pain during physical activity (6 left, 2 right, 1 bilateral); none reported knee pain at rest or further arthralgia (coxalgia, pain in the ankles or feet); only one athlete uses contact lenses during sports; six athletes reported untreated bruxism; no athlete wears or has worn orthotics in the past 24 months.

The analysis of plantar support showed statistically significant variability in 6 values: left Arch index (p=0.004), right Staheli index (p=0.042), midfoot symmetry (p= 0.030), isthmus symmetry (p= 0.048), arch length symmetry (p=0.027), height of the left plantar arch (p-value 0.009). There was no statistically significant variability for the other values. No statistically significant differences were found based on the role in the field (as described by Table I).

The postural analysis showed statistically significant variability in only two values: rotation of the pelvis (p=0.013) and kyphotic angle (p=0.050). There was no statistically significant variability for the other values. There were no statistically significant differences based on the role in the field (see Table 2 for further details).

Discussion

The study aims to analyze how sporting activity changes posture in healthy athletes over the course of an entire season and whether these changes can be the cause of in-jury. We chose to study rugby players, as the great physical and competitive de-mand of this sport is the cause of many injuries and the relatively recent increase in the number of players has led to the production of many studies that try to analyze the mechanisms, incidence, and risk factors of injuries, but the literature is now inconsistent and not unanimous.[1,2] The literature is not uniform on which period of the season has an increased incidence of injuries. Some authors claim that the first few months of the season are the most dangerous, others assert that the incidence peaks after a mid-season break, others that 70% of injuries occur in the late stages of the season.[7,36-41] Numerous studies claim that most injuries occur in the second half of the game, involving fatigue and reduced motor control.[6,7] Studies conducted prior to the introduction of professionalism in Europe (1995) suggest that the roles most at risk of injury are hookers, back rows, centers, wingers and full backs.[42] Recent studies, on the other hand, are very contrasting with each other and, while offering a picture that seems to put the second rows and scrum-halves in the lead for the number of injuries, do not offer satisfactory relevance and concordance.[1,3,6,9,43-46]

The analysis we conducted by questionnaire confirms the preponderance of musculoskeletal injuries, but adds an interesting fact, namely that most of the injuries affect the left lower limb compared to the contralateral: left knee pain in six cases out of nine (one bilateral knee pain, two right knee pains); four athletes also reported muscle injuries to the left knee flexors versus one case of right knee flexor injury. Only one athlete reported the simultaneous presence of knee pain and previous muscle injury to the left lower limb. This data is related to the distribution of laterality in the group, which includes twenty-three right-handed, two ambidextrous (right -handed, left-footed) and one left-handed.

The analysis of plantar arch shows how athletes tend to have an increase in the cavity of the left foot during the most intense phases of the season, when physical effort is at its peak during the week. This feature is reduced in T1 and T2, when the physical effort is less intense, and the data obtained from the analysis of the plantar support are more symmetrical.

The increase in the left foot arch can be found in all the values relating to the midfoot: Arch index, Staheli index, midfoot symmetry, isthmus symmetry, length and height of the right and left foot arch. The maximum statistical significance was found between the times T0 and T1, that is, between the period of maximum and minimum training.

The laterality of the data is consistent with the distribution of the group, which includes twenty-three right-handed, two ambidextrous and one left-handed and might correlate to the non-traumatic nature of most of the injuries reported by the players. The tendency of the left foot to cavity could partly favor the high number of non-traumatic injuries of the lower limb and must be correlated with the risk factors identified by other studies. The plantar support, which is altered in midfoot values, could be the cause of an asymmetrical technical gesture that would favor the onset of injuries and painful symptoms. Non-right-handed athletes, on the other hand, show an inconsistent trend in measuring the foot arch in the three periods, so it is not possible to affirm that support changes as a result of the quality and quantity of training. The data extracted from the analysis can find a rationale in the athlete's request to the leg muscles, which could show hyperactivation and lead to a claw foot shape of the arch. Another motivation can be found in the technical gesture of passing: the right-hander passes the ball more easily from right to left, using the "weak" foot as support and point of balance. It will certainly be necessary to deepen this data by evaluating a greater number of left-handed rugby players and athletes who practice asymmetrical sports, to make the study sample more heterogeneous.

Formetric4D has allowed us to study postural deformities of the spine by means of videorasterstereography. The analysis of the spine shows that during the season the athletes change the rotation of the pelvis and the kyphotic angle. The change in pelvis rotation is more evident in T0 than in the other two periods. The median of the ky-photic angle appears to be regular only in T2 (pre-season), while in T1 (off-season) it shows the value most different from the normal range.

Training, therefore, allows players to have a more correct and more symmetrical spinal and pelvic postural structure, probably thanks to the strengthening of the pelvis, abdomen, and back muscles. This data correlates with the low prevalence of injuries of the spine and upper limbs among the subjects analyzed. The homogeneity of results appears in contrast with previous studies, without distinction based on the player role. It will be necessary to investigate the correlation between the most suitable values for the description of "correct posture" and the high prevalence of back pain among athletes. Our study underlines the need to investigate the postural variations of competitive athletes during the sporting season to limit the possibility of injuries related to the technical gesture.

To date, to the best of our knowledge, this study represents the first correlation study between postural changes and injuries in professional rugby players, carried out with instruments that guarantee objective and repeatable measurements of numerous postural parameters. We are aware that the present study is not free form limitations: first, the study design that did not consent to draw strong conclusions; second, the small sample size of players involved in the study; lastly, the homogeneity of the group's sporting level.

Conclusions

Taken together, our findings describe a cavity of the left foot during the intense phases of the season which could correlate to the clinical history of the subjects examined, which describes a prevalence of injuries or painful symptoms in the non-dominant lower limb. The high incidence of non-traumatic injuries in rugby could be sought in this data and be corrected through specific training aimed at creating a postural structure as symmetrical as possible. The present proof-of-principle study also shows that the training conducted by the athletes examined correlates to improved rotation values of the pelvis and kyphotic angle of the spine, thought it does not reduce the widespread painful symptoms affecting the spine; these could instead be traced back to the important physical impacts that this sport requires and would therefore be difficult to reduce with postural rehabilitation alone.

It will be necessary in the future to conduct studies that include rugby players with different characteristics, as well as other athletes from symmetrical and asymmetrical sports. It will also be interesting to insert postural interventions during the season to analyze how these can modify the collected data.

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None.

Authors' contribution

Conceptualization, F.A., A.d.S., A.B., M.M.; methodology, A.d.S., M.P.; formal analysis, F.A., M.M.; investigation, F.A., G.D.G., M.Mu., A.D.C.; resources, M.P.; data curation, F.A., A.d.S., A.B., N.N.; writing—original draft preparation, F.A., A.d.S.; writing—review and editing, A.B., M.M.; visualization, G.D.G., M.P., M.M., A.D.C., A.A.; supervision, M.P., A.A.; submission, A.d.S. All authors read and approved the final version of the manuscript.

Declaration of interest

The authors certify that there is no conflict of interest in any way with any financial organization regarding the material discussed in the manuscript.

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Figure Legend

Figure 1. 3D PodoScanalyzer.

Figure 2. Formetric4D.

Table I. Statistical analysis of the data obtained through the 3D PodoScanalyzer.

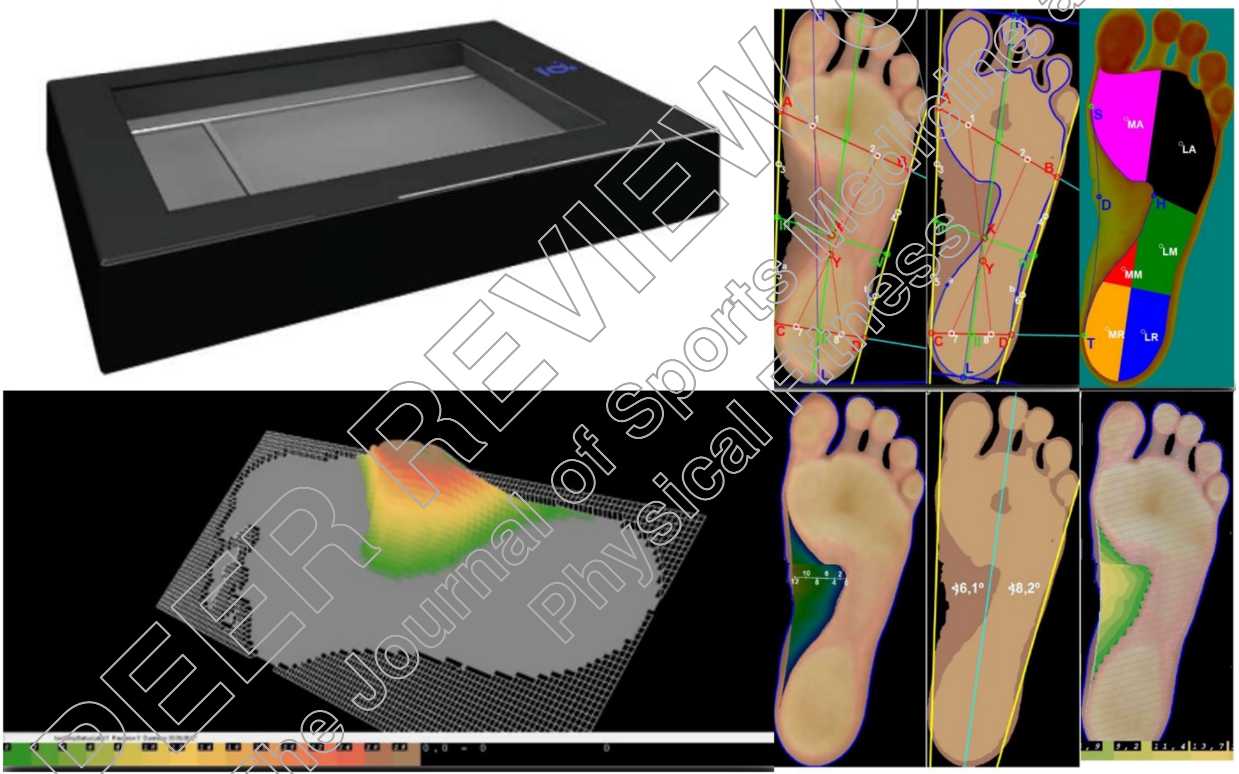
	T0, Median (min-max)	T1, Median (min-max)	T2, Median (min-max)	*p*-value	*p*-value T0-T1	*p*-value T1-T2	*p*-value T0-T2
Arch Index R.	0.29 (0.18-0.39)	0.28 (0.19-0.38)	0.27 (0.18-0.42)	0.962	-	-	-
Arch Index L.	0.26 (0.15-0.41)	0.28 (0.19-0.51)	0.28 (0.18-0.39)	0.004	0.003	0.113	0.636
Staheli index R.	0.68 (0.39-0.78)	0.67 (0.61-0.72)	0.66 (0.57-0.85)	0.042	0.124	1.000	0.049
Staheli index L.	0.65 (0.59-0.70)	0.66 (0.61-0.74)	0.67 (0.61-0.79)	0.144	-	-	-
Podalic Symm. Index	0.08 (-1.15-0.55)	-0.01 (-0.98-0.48)	-0.01 (-1.12-0.50)	0.448	-	-	-
Metatarsal Symm. Index	0.31 (-3.5-1.97)	0.07 (-1.68-1.41)	-0.02 (-1.41-2.29)	0.334	-	-	-
Midfoot Symm. Index	0.11 (-0.45-0.81)	-0.06 (-0.42-0.60)	-0.03 (-0.84-0.75)	0.030	0.025	0.802	0.381
Isthmus Symm. Index	0.05 (-0.24-0.41)	-0.04 (-0.22-0.28)	-0.02 (-0.42-0.36)	0.048	0.046	0.802	0.563
Plantar arch Symm. Index	-0.18 (-1.4-1.26)	0.08 (-0.82-1.64)	0,14 (-1.14-0.69)	0.027	0.249	1.000	0.025
Hindfoot Symm. Index	-0.10 (-0.40-3.92)	-0.09 (-0.38-0.76)	-0.08 (-0.78-1.14)	0,971	-	-	-
Calcaneal length Symm. Index	-0.09 (-2.21-9.39)	-0.03 (-2.12-0.74)	-0,15 (-1.69-1.86)	0.962	-	-	-
Calcaneal semicircle Symm. Index	-0.15 (-2.43-21.51)	0.00 (-3.53-2.21)	-0.27 (-3.14-2.10)	0.354	-	-	-
Plantar angle Symm. Index	0.39 (-1.79-6.63)	0.83 (-2.02-4.49)	0.46 (-5.11-2.61)	0.076	-	-	-
Tarsal epicenter Index	-0.29 (-8.29-30.36)	-0.12 (-7.35-2.71)	-0.65 (-6.70-7.20)	0.764	-	-	-
Medial subtalar variation	1.57 (-12.94-12.53)	-0.96 (-24.10-11.14)	-1.35 (-62.00-11.78)	0.354	-	-	-
Lateral subtalar variation	-0.37 (-30.31-19.95)	-1.27 (-22.49-15.80)	0.44 (-23.17-20.54)	0.962	-	-	-
L. Plantar arch Index	1.41 (0.83-2,25)	1.13 (0.64-2.14)	1.25 (0.61-2.37)	0.009	0.011	1.000	0.067

R. Plantar arch Index	1.21 (0.00-2.34)	1.16 (0.38-4.82)	1.37 (0.57-5.34)	0.354	-	-	-
L. Longitudinal plantar angle Index	14.34 (7.95-16.94)	14.21 (10.39-17.50)	14.47 (11.62-18.22)	0.112	-	-	-
R. Longitudinal plantar angle Index	14.68 (12.16-17.38)	14.86 (12.26-17.55)	14.97 (9.58-19.14)	0.223	-	-	-
Postural Biomechanical Index	9 (2-24)	9 (2-23)	11 (1-21)	0.406	-	-	-

Abbreviations: R: right; L: Left; Symm: Symmetry.

Table II. Statistical analysis of the data obtained through Formetric4D.

	Median T0 (min-max)	Median T1 (min-max)	Median T2 (min-max)	*p*-value	*p*-value T0-T1	*p*-value T1-T2	*p*-value T0-T2
Lateral flexion	-5.25 (-25.50-13.50)	-5.11 (-30.00-7.50)	-6.00 (-30.00-9.00)	0.143	-	-	-
Pelvic tilt	0.00 (-30.00-15.00)	0 (-9.00-18.00)	0.00 (-12.00-12.00)	0.750	-	-	-
Twisting of the hemipelvis	2.03 (-3.00-11.90)	1.99 (-4.52-6.61)	1.57 (-6.36-5.46)	0.432	-	-	-
Pelvis rotation	0.41 (-5.43-11.71)	-1.55 (-7.84-3.72)	-1.59 (-8.91-6.99)	0.013	0.022	1.000	0.049
Cervical arrow	57.97 (20.67-89.52)	60.30 (27.34-90.32)	55.70 (0.00-92.90)	0.320	-	-	-
Lumbar arrow	49.27 (21.85-71.89)	50.42 (20.03-65.12)	44.89 (15.42-71.69)	0.619	-	-	-
Kyphotic angle	45.33 (30.76-70.84)	47.78 (29.97-69.69)	44.49 (27.60-68.68)	0.050	0.102	1.000	0.102
Lordotic angle	42.14 (29.50-64.23)	41.40 (28.59-59.40)	40.92 (26.47-59.94)	0.595	-	-	-
Superficial rotation of spinous processes (mean)	3.18 (0.91-6.78)	3.08 (0.84-5.34)	2.98 (1.00-5.52)	0.527	-	-	-
Superficial rotation of spinous processes (max)	-3.09 (-7.38-11.02)	-3.19 (-8.28-10.45)	3.98 (-8.85-11.25)	0.595	-	-	-
Lateral deviation (average)	4.05 (1.28-7.85)	4.01 (1.86-7.55)	3.91 (1.86-8.77)	0.961	-	-	-
Lateral deviation (max)	2.56 (-13.06-14.51)	5.23 (-12.50-12.55)	-3.15 (-12.08-14.20)	0.887	-	-	-
Lateral deviation (amplitude)	10.82 (2.97-18.92)	9.33 (4.77-21.42)	9.73 (3.21-19.27)	0.852	-	-	-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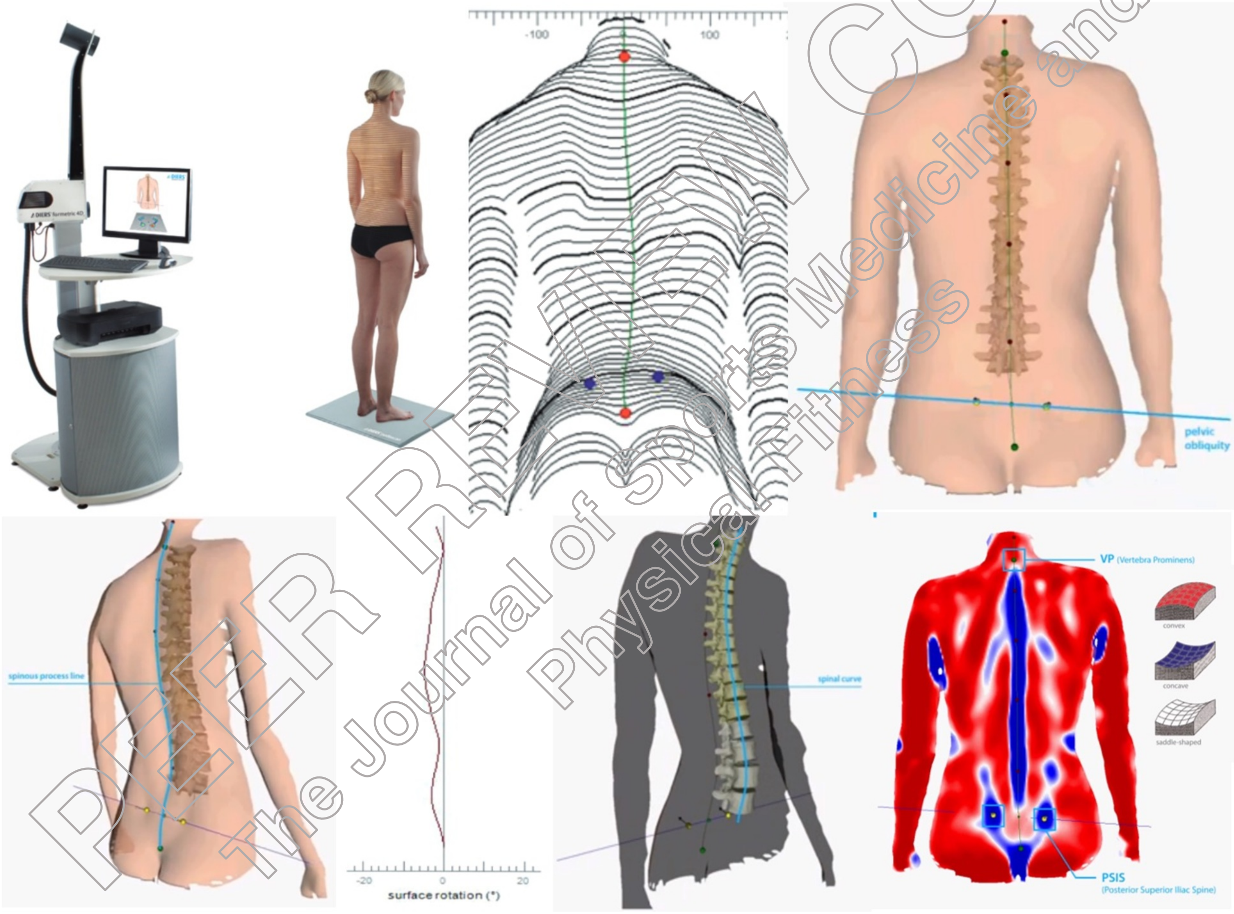
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surface rotation (°)
spinal curve
VP (Vertebra Prominens)
convex
concave
saddle-shaped
PSIS (Posterior Superior Iliac Spine)