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# The sub-base of an artificial turf rugby field has an effect on the vertical loading rate during impact

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## 1. Introduction

The influence of sports surfaces, particularly third-generation artificial turf, on athletes' performance and injury risk, is under increasing scrutiny. These turfs, composed of multiple layers with distinct materials, aim to enhance players' safety and surface playability. Despite FIFA and World Rugby implementing quality programs using assessments conducted with the device "Advanced Artificial Athlete" (AAA), debates persist regarding the capacity of the latter to mimic players' experiences, especially in high-load actions such as scrums or cuttings (Atack et al., 2020). The contact time is too brief (Cole et al., 2023). The same challenge arises for equestrian surfaces used for racing or competing. This is why our research group has developed the *Equine Track Tester* (ET2), designed from ground reaction force measurements on horses under sport conditions (Crevier-Denoix et al., 2021). The purpose of this study was to compare using the ET2 the mechanical behavior of two rugby fields (A and B) only differing by their sub-base structure. Given the high energy and loading pattern provided by the ET2, the hypothesis was that tests performed with this device would reveal, for loading levels encountered in rugby, differences in the dynamic responses of both fields due to their sub-base difference, explaining the reported medical issues.

## 2. Methods

### 2.1 Fields

Fields A and B, located in the same city area, were built at one year interval. Field B, only used for training, was designed to duplicate field A, used for both matches and training. Both fields are outfitted with the same artificial turf, supplemented by 8 kg/m<sup>2</sup> of SBR infill and 35 kg/m<sup>2</sup> of sand over a 24 mm shock pad. Underneath these first 64 mm, sub-base consists in 30 cm of 4 to 20 mm gravel element size in A, and 15 cm of 0 to 20 mm in B.

Measurements were requested after players (especially heavy ones) and medical staff complained about field B being harder and more injury-prone than field A, and while AAA measurements were not conclusive.

### 2.2 Testing apparatus

The ET2 has been designed to simulate the action of an equine forelimb on the ground under sport conditions, both in terms of maximal vertical force and loading rate. A test consists in the dropping of a 110 kg mass, sliding along a vertical axis connected with a hoof-shaped impactor in contact with the ground. After a first phase of free fall (30 cm), the mass pushes the axis-impactor system down inducing ground loading, the rate of which is decreased by the tension of an elastic device (patented) which mimics the action of the musculotendinous system. The impactor is equipped with a uniaxial force sensor (Kistler, 9343AU) and a displacement sensor (Micro-Epsilon, WDS-250-MPM-C-P-HG).

### 2.3 Testing procedure

Each field was tested on 12 locations spread across the field in the most used areas during matches. To avoid any bias, fields were alternated: first set of tests at 6 locations in field A, followed by the 12 tests in field B, then the remaining 6 tests in field A.

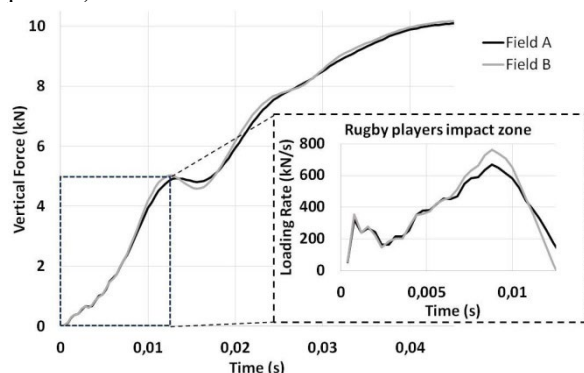
### 2.4 Data processing and analysis

From each ET2 test, the following variables were determined: maximal vertical force, maximal sinking (vertical displacement of the impactor), incremental loading rate (slopes of the force-time curve), incremental stiffness (slopes of the force-sinking curve). Focus was placed on forces below 4 kN in agreement with the literature reporting maximal forces generated by rugby players (Atack et al., 2020). To compare fields A and B, a two-sample t-test was used for dataset with confirmed normality and equality of variances, otherwise a Mann-Whitney U-test or Welch t-test (respectively) was used. All analyses were performed on RStudio.

## 3. Results and discussion

Three loading phases were discriminated: 1-2, 2-3 and 3-4 kN. Maximal vertical force was slightly but

significantly higher on field B compared to A (Fig.1; +0.9%,  $p=0.04$ ), while the inverse trend was observed for maximal sinking (-8.1%,  $p=0.06$ ) (Table 1). The loading rate was significantly higher on field B for the 3-4 kN range (+15%,  $p<0.001$ ), but not for the 1-2 kN and 2-3 kN ranges. Similarly, stiffness values tended to be higher on field B for the 3-4 kN range (+11%,  $p=0.06$ ).



**Figure 1.** Average vertical force-time curves obtained on the two rugby fields studied. The loading rates as a function of time, for loads expected in rugby, are presented in the zoom window.

There is a clear trend for an increased firmness of field B compared to A. In terms of loading rates, the increasing difference between both fields for forces from 2 to 4 kN, with no difference observed below 2 kN, is consistent with the structural difference being located from a 64 mm depth.

**Table 1.** Means (sd) of the ET2 variables determined on rugby fields A and B.

	Field A	Field B	P
Max Vertical Force (N)	10 092 (122)	10 179 (67)	0.04
Max Sinking (mm)	15.6 (1.9)	14.3 (1.0)	0.06
Loading Rate			
1-2kN	399 (39)	392 (25)	0.59
2-3kN	589 (58)	617 (36)	0.17
3-4kN	670 (71)	772 (40)	<0.001
Stiffness			
1-2kN	404 (47)	384 (27)	0.24
2-3kN	424 (66)	432 (39)	0.73
3-4kN	534 (91)	594 (44)	0.06

A 4 to 20 mm gravel is expected to be more damping and deformable under compression compared to a 0 to 20 mm gravel, more prone to compaction. Introducing damping elastic elements in the sub-base of an artificial turf has proved to reduce force reaction and energy restitution, which could be beneficial for athletes (Sánchez-Sánchez et al., 2019). In the present study, the increasing firmness observed for forces above 2 kN is also consistent with the reported medical issues, mainly concerning the heaviest players. The loading rate induced by a sport surface is one of the variables most sensitive to ground firmness, and it has been associated with osteoarticular and musculotendinous injuries (Johnson et al., 2020).

## 4. Conclusion

The differences in dynamic response of the two rugby fields under study, as revealed by the ET2, can explain the medical issues reported. This experiment highlights the interest of using the ET2 in the context of high loading situations, even in human sports.

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## Conflict of Interest Statement

No author has any conflict of interest.

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