Article
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Is clay court the best tennis surface? A narrative review

¿Es la cancha de arcilla la mejor superficie en el tenis? Una revisión narrativa

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Abstract

aThis paper aims to demonstrate that clay courts are likely the most suitable playing surfaces in terms of muscle contraction, efficiency and the reduction of risk factors associated with the viscoelastic and frictional properties of the surfaces themselves. The style of play, with more or less frequent accelerations, decelerations and changes of direction, the duration of the match and the frequent tournaments on different playing surfaces can be additional risk factors. In fact, it has been shown that muscles are sensitive to surface stiffness and that frequent playing on different surfaces can be associated with lower limb injuries. Furthermore the busy calendar of ATP (*Association* of Tennis Professionals) and WTA (*Women's* Tennis Association) is stigmatised because it is characterized by the sudden transition from hard to clay and/or clay to grass without the necessary gradualness, thus preventing proper motor adaptation. The aims of this work emerge from literature and from a biomechanical-theoretical analysis of the loads that result in the musculoskeletal system by human and playing surface interaction.

Keywords: *Tennis surfaces, clay court, hard court, grass court, injuries.*

Resumen

Este artículo tiene como objetivo demostrar que las canchas de arcilla son probablemente las superficies de juego más adecuadas en términos de contracción muscular, eficiencia y reducción de factores de riesgo asociados con las propiedades viscoelásticas y de fricción de las propias superficies. El estilo de juego, las aceleraciones, las desaceleraciones, los cambios de dirección más o menos frecuentes, la duración del partido y los torneos frecuentes en diferentes superficies de juego pueden ser factores de riesgo adicionales. De hecho, se ha demostrado que los músculos son sensibles a la rigidez de la superficie y que jugar frecuentemente en distintas superficies puede estar asociado con lesiones en las extremidades inferiores. Además, se critica el calendario saturado de la ATP (Asociación de Tenistas Profesionales) y la WTA (Asociación de Tenis Femenino), ya que se caracteriza por incluir transiciones abruptas de superficies duras a arcilla o de arcilla a césped sin la gradualidad necesaria, lo que impide una adaptación motriz adecuada. Los objetivos de este trabajo surgen tanto de la literatura como de un análisis teórico-biomecánico de las cargas que se generan en el sistema musculoesquelético por la interacción entre el ser humano y la superficie de juego.

Palabras clave: *superficies de tenis, cancha de arcilla, cancha dura, cancha de césped, lesiones.*

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Introduction

In tennis, a fundamental role, both for performance and for the possible onset of pathologies or injuries, is played by the components characterizing the game (Allen et al., 2019). The development and production of innovative playing equipment and surfaces, which in theory can be more performing, do not always guarantee the expected results in terms of quality of performance (Lakotos et al., 2024) and safety of practitioners. If, at the highest levels, problems often arise due to the intensity and frequency of performances (Moreno-Pérez et al., 2021), at an amateur level one of the main causes of injuries, due to technological peculiarities, lies in the lack of awareness of how much the shoe and the surface mediate the transfer of loads between man and the surrounding environment. Any modification of these components involves the redistribution of mechanical stresses on the biological system, with effects that are difficult to predict without the necessary knowledge of its potential and limits. In fact, even if we assume that manufacturer provides an accurate description of the mechanical properties of the tool, we cannot forget the individuality of the human being (anthropometric differences, muscular conformation and biological response to stimuli). It follows that we need a more in-depth knowledge of both components (man and tool) to obtain the best coupling according to the chosen final objective.

Various research has shown how, during a tennis match, the game can be altered by various factors intrinsic to the sport, such as the type of surfaces (clay, hard, grass), gender, different tactical behaviours (the big server, serve and volleyer, all-court player, attacking baseliner, solid baseline, counter puncher) and thermal stress (Kramer et al., 2017; Morante & Brotherhood, 2008; Hornery et al., 2007; O'Donoghue & Ingram, 2001; Smekal et al., 2001). All these variables can influence the match as well as the individual physiological conditions.

As to the playing surface, some studies have analysed how the type of surface influences the bounce of the tennis ball and, consequently, its speed and the game characteristics (Groppel & Roetert, 1992). Slower surfaces, such as clay, are characterized by greater friction. This friction results in a moderate bounce of the ball: this event allows the player to have more time to prepare to hit compared to when he tries his hand on hard surfaces (Haake et al., 2003).

As a consequence, an important factor emerges: competing on different playing surfaces involves an adaptation of the movements with important kinetic changes that produce different stress patterns on the lower limbs joints. This evidence is well known in training practice: the players' muscles should be trained in such a way as to generate optimal forces during the different levels of movement considering the playing surface (Verstegen, 2003).

A further parameter to consider is the lactate concentration. It has been shown that it is not significantly different between clay and hard courts (Girard & Millet, 2004). The slight discrepancies are probably a result of differences in the characteristics of the subjects (number, playing ability, age, height and body mass).

In tennis, fatigue can be related to prolonged effort or high physical intensity (Hornery et al., 2007). The mentioned authors made a series of comparisons on players playing tennis on different surfaces and came out with the following consideration: tennis matches played on clay are physically more demanding than those played on fast courts. From here, it can easily be deduced that tiredness induced by more intense physical effort can hinder performance. This suggests the need for more accurate methods for monitoring training intensity during tennis practice.

Two methods to measure tennis court speed: CPI and CPR

The International Tennis Federation (ITF) distinguishes four key properties of a tennis court surface (Capel-Davies et al., 2015):

- *Friction*, i.e. the resistance encountered by an object sliding on a surface. In this context it is the tangential force encountered by the tennis ball or by the player's shoes in the relative motion with respect to the surface of a tennis court. It is defined by the coefficient of friction (COF), corresponding to the ratio between the tangential force and the force normal to the surface. A surface with greater roughness has a higher COF, which results in a greater deceleration of the horizontal speed of the ball, consequently making the play on the surface perceived as slower. The effect of friction on the shoes is to reduce their sliding possibility, increasing the braking force.
- *Energy dispersion*, referring to the tennis ball during the impact on the surface, is measured through the coefficient of restitution (COR), i.e. the ratio between the vertical speed of the ball after the bounce and that before impact. COR is an indicator of how efficiently an impact restitutes the kinetic energy to the ball, and depends on the characteristics of both materials in contact. A surface with a higher COR is generally perceived as slower, as the ball will reach a greater height after impact, thus allowing an increase in the time available to reach the ball.
- *Topography and dimensions*, i.e. surface uniformity, size and slope.
- *Consistency*, i.e. the uniformity of surface properties across the entire playing area and their stability over time.

There are two different methods for classifying the speed of a tennis court: Court Pace Index (CPI) and Court Pace Rating (CPR). The CPI, which is a measure deriving from the data collected by "Hawk-Eye" through a triangulation camera system, shows the performance of the fields in real matches and consists of an average of multiple kinematic variables calculated over the seven days in which an ATP tournament is played. The CPR, on the other hand, measures the effect of the interaction between the surface and the tennis ball and is calculated with a test that uses a ball-shooting machine and a complex piece of equipment, known as Sestée.

Officially, the ITF regulates the criteria and procedures for classifying playing surfaces by dividing them, through the CPR, into five categories: slow, medium-slow, medium, medium-fast, fast (Table 1).

Table 1
Classification of playing surfaces according to the CPR

Type of surface	CPR
Slow	≤29
Medium-slow	30-34
Medium	35-39
Medium-fast	40-44
Fast	≥45

The measurement of CPR, through the Sestée, is regulated by the ITF itself and requires careful and precise calibration of the instrument. Mathematically, the CPR is a function of both the coefficient of friction (COF) and the coefficient of restitution (COR), according to the formula:

$$CPR = 100 \cdot (1 - COF) + 150 \cdot (0.81 - COR)$$

The first term [100·(1-COF)] is the Surface Pace Rating (SPR) i.e. the measurement system that was adopted before the definition of CPR itself. The second term [150·(0.81-COR)], referred as K, represents the individual perception factor of the tennis player in relation to a given surface. The first term is a function of the COF and inversely proportional to it (it increases as the COF itself decreases). The calculation of the COF is done in the laboratory and is often linked to the use of complex equipment (Cross, 2010). A fast surface has a higher SPR (lower COF) than a slow surface (Cross, 2010; Cross, 2003; Cross & Lindsey, 2019; Martin & Prioux, 2014). The second term (K) includes the number 0.81 (average restitution coefficient for all types of surfaces) and the number 150, which represents the rhythm perception constant. It is determined through empirical research and calibration processes that aim to match CPR to players' perceptions of playing speed on different surfaces. CPR is the result of a balance between objective measurements of the physical properties of the courts, such as COF and COR (Table 2), and the subjective assessments of the players on the perception of the speed of the court (Cross, 2010).

Table 2
Summary table of CPR, COF and COR values of clay, hard and grass tennis courts

Type of tennis courts	CPR	COF	COR
Clay	23	>0.71	0.86
Hard	35-39	0.56-0.70	0.79-0.84
Grass	46*	<0.55	0.77*

* According to Miller (2006) and Brody (2003).

Choosing a value of 150 ensures that the CPR formula accurately reflects the gaming experience, considering how the physical characteristics of the surface influence the human perception of game speed.

The COR measurement is obtained by comparing the bounce and fall heights of a sphere, as occurs in the normal drop test (Haron & Ismail, 2012). Furthermore, a methodology has recently emerged that aims to use a low-cost portable apparatus (Colombo et al., 2016; Espinosa et al., 2016).

In summary, playing surfaces - clay, hard, grass - are strongly differentiated in terms of CPR. On clay, the ball's horizontal advancement speed is slowed down, and bounces are facilitated, which favour prolonged rallies. Unlike grass which, having a high CPR, penalizes the vertical bounce speed, keeping the ball closer to the ground. Finally, the concrete surfaces, which have a variable CPR and are halfway between clay and grass, provide a moderate playing speed and a higher rebound, when compared with the typical surfaces of Church Road (Wimbledon) and all those in preparation for the third slam of the year.

Playing surfaces and injuries

Moving on now to consider the athlete's interaction with the ground, a first aspect concerns the ability of the ground itself and the athlete's muscular system to absorb fall energy. If we consider the impact of a rigid body on a yielding surface, we will find two important differences compared to what happens with a rigid surface. In the first case, the phenomenon develops with greater surface deformations and the contact force has a lower peak value and longer duration. In the second case, simplifying, we can state that if the surface is rigid, the impact is more rapid and violent.

The effects of the foot-ground impact on the "human system" also depend on the "global rigidity" of the biological system, i.e. on its instantaneous mechanical characteristics. These characteristics are determined by the combined contribution of the passive components (bones, ligaments, etc.), the active ones (muscles) and the segmental and joint kinematics. The subject is able to vary - within certain limits - his “global stiffness” in order to control and, if necessary, reduce the loads to be supported. The strategy adopted is to modify the level of contraction of the muscles involved and to use adequate motor strategies (see controlled flexion of the knees in order to absorb the impact of a downward jump).

Tennis could be played on more or less soft ground and the amount of energy dissipated by the ground itself affects the energy demand on the muscular system. A soft ground, if truly elastic, returns a large part of the energy absorbed, helping to reduce the consumption of metabolic energy. Even rigid (non-deformable) ground produces the same effect, as it does not absorb energy. Otherwise, an inelastic surface - such as clay - absorbs a large part of the deformation energy, dissipating it into heat. As previously reported, different properties of the surface do not affect the global physiological parameters like lactate, while muscle intervention is strongly affected by them. As regards aspects of muscle physiology, it is known that a concentric contraction, preceded by an eccentric contraction, is associated with a reduction in metabolic energy consumption. The esploitation of this mechanism is partly connected to the elastic characteristics of the court. In fact, if we assume that the ground and the athlete (who, for simplicity, we will call ’the muscle’) can be schematised as a system of two springs in series, the total energy L absorbed during the impact is given by the sum of the energy absorbed by the ground (L_g) and that absorbed by the muscle (L_m):

$$L = L_g + L_m \quad (1)$$

For ideal springs, F=$k\Delta x$ (k is the stiffness and Δx is the deformation).

The accumulated elastic energy for a given deformation is $Le = \int F\,dx = \int k\,\Delta x\,dx = (1/2)\,k\,(\Delta x)^2$

With reference to equation (1) we have

$$Lg = (1/2)\ kg\ (\Delta x_g)^2\ e\ L_m = (1/2)\ k^m\ (\Delta x_m)^2$$

Where kg e $(\Delta x_g)^2$, k_m, ΔX_m and are, respectively, stiffness and deformation of the two springs.

In this model, consisting of two springs in series, the force F acting on each spring is the same; it is therefore possible to obtain the deformation of each component:

$$\Delta x_g = F/K_g$$

$$\Delta x_m = F/K_m$$

This means that the stiffer spring (higher k) will experience smaller deformations than the more compliant spring. The work absorbed as a function of force is expressed as follows:

$$L = (1/2)\ k\ (\Delta x)^2 = (1/2)\ k\ (F/k)^2 = (1/2)\ F^2\ /\ k$$

It follows that the stiffer spring (high k), which undergoes smaller deformations, will absorb less energy than the more compliant one. During the execution of a certain gesture, when the athlete lands on a very soft surface(small k_g), that surface will deform considerably, absorbing more energy than when the athlete lands on a rigid surface.

For a given amount of total energy absorption:

$$L = L_g + L_m$$

If the energy absorbed by the ground increases, the energy absorbed by the muscular system will decrease.

In this situation (yielding surface), the muscle’s ability to store elastic energy, and then release it to support the contraction, is certainly penalized. If, however, the playing surface is rigid (large k_g), the muscle can absorb a considerable amount of elastic energy and then return it to the benefit of its mechanical performance.

However, it should be considered that the notable difference between the deformation of the ground and of the muscular system Δx_m (for Δx_m we can consider the vertical position change of the center of gravity of the athlete with respect to the ground during the impact) leads us to believe that the k_g is considerably greater than k_m and therefore the energy absorbed by the ground during landing from a jump is very small compared to that absorbed by the muscular system, at least for the playing fields usually used.

Therefore, the difference between various playing fields will have little influence on the energy demand from the muscular system (significant effects could be observed only if, for example, extremely deformable terrains were considered). Different considerations apply regarding the aspect of horizontal sliding. Epidemiological studies indicate strong correlations between the number of micro events during the play and the type of terrain. Players accustomed to surfaces that allow controlled sliding (clay) - where, for the same impulse, the longer braking time implies the achievement of lower maximum forces - are affected by significantly fewer painful situations or injuries compared to those who play tennis on hard surfaces, such as concrete or asphalt (Nigg & Yeadon, 1987; Dragoo & Braun, 2010). This statement is also confirmed in an even more recent study which refers precisely to surfaces that allowed for controlled sliding: the injury rate on clay courts is lower than that on hard courts, which is believed to be due to lower friction (Starbuck et al., 2015). These findings have a clear biomechanical justifications if we consider that, for example, the horizontal component of the Ground Reaction Force (GRF), in some shots, is three times higher on hard surfaces than on common clay courts (Tiegermann, 1984).

Ground Reaction Force (GRF) is one of the main external forces that act on the human body in contact with the earth's surface. Since this force balances the body weight and the inertia forces of the center of gravity, it is directly related to the movement performed (Chow et al., 1999). It is also an important component for estimating the internal forces that act on the musculoskeletal system. GRF is measured with dynamometric platforms, made up of a rigid plane of rectangular or square shape, usually supported in four points by force sensors assembled in load cells. The load cells are constrained to a rigid support base, which is in turn constrained to the ground (Van Gheluwe & Hebbelinck, 1986).

Synthetic surfaces, due to the high COF, amplify the critical issues imposed by the starting, stopping and changing direction phases. Taking the same braking as an example, where the tennis player (of mass m) reaches the ball with a given speed (V_0) and slides on the surface, the initial momentum ($Q = mv_0$) will be dampened by the friction force which will act throughout braking time. This force is transmitted to the musculoskeletal-tendinous system and, the greater the friction force, the greater the load applied to the musculoskeletal-tendinous system.

To reduce the momentum to 0, the friction force F must act for a time determined by the following equation:

$$\Delta Q = m(v_o - 0) = \int_0^{\Delta t} F dt \quad (2)$$

In fact, for a decelerating mass, $F = mdv/dt$ for which $mdv = Fdt$ (dt is the time differential, i.e. an infinitesimal time variation). By integrating this equation over time we obtain equation (2). If we assume that the force F is constant over time, the integral of (2) leads to:

$$\Delta Q = m\Delta v = F\Delta t$$

It can therefore be argued that an increase in friction force corresponds to a reduction of the momentum in a shorter time. In fact, the same change of momentum can be obtained by applying a greater force for a short period or a smaller force for a longer time. Increased grip strength (short time) leads to a consequent increase in the loads on the biological system. It is therefore useful to refer to the study by Strauss (2006), who focused on two mechanical properties: stiffness and deflection. First of all, stiffness means the ability of a body to oppose the elastic deformation caused by an applied force. In the elastic field for small deformations, the deformation is proportional to the applied stress (Hook's law). The coefficient of proportionality is Young's modulus, which measures the resistance of materials to elastic deformation for states of simple tensile or compressive stress. Its unit of measurement is the Pascal (Pa = Newton / m^2). Young's modulus is usually reported in MegaPascals (MPa) for polymers or in GigaPascals (GPa) for stronger materials such as metals. The term deflection, however, refers to the deformation that a body undergoes when subjected to a force. It can be expressed directly, both with the value of ΔL in mm, and with the ratio between deformation and initial length L_0, which is called the strain $\varepsilon = \Delta L / L_0$).

Well, it is highlighted that the grass surface is less rigid than the clay one and even less rigid than the artificial surfaces (Strauss, 2006). The high rigidity of synthetic surfaces can be correlated, together with the damping component, to considerable impact forces. This characteristic, associated with the high friction coefficient, is compatible with the greater occurrence of accidents. The clay-grass comparison is more complex. Clay court appears stiffer than grass, but we are not aware of precise data on damping. It is therefore difficult to hypothesize comparisons between the impact forces that can develop on the two terrains. Furthermore, the strong dependence of the physical and mechanical characteristics on environmental conditions also makes it difficult to speculate on the friction coefficient.

Natural grass courts present further and different variables in relation to environmental and climatic factors, such as the influence of humidity on the aforementioned friction coefficient. The dynamic or sliding friction coefficient on dry grass is 0.40-0.50, while on wet grass - a widespread condition in gloomy London, home of the renowned Wimbledon tournament - the value is around 0.30-0.40. This is an extremely interesting figure, especially when compared to that relating to ice (0.15) and concrete (0.60). The potential lack of adhesion, therefore, depends (also) on the state of the turf (in addition to unfavorable weather conditions, we remember the wear and the presence of light patches due to some plant disease), and is configured as a risk factor for the tennis player's foot-ankle structure.

Synthetic grass fields are essentially divided into two categories: those which have an infill of a specially developed polymer between the blades (of grass) and those that use simple shredded tires. Both solutions present the problem of accentuated heating due to increased solar radiation.

In particular, the aforementioned phenomenon is more accentuated for carpets with a filling based on shredded tires, which can be associated with the emission of volatile organic compounds (VOCs) and unpleasant odors.

Compared to synthetic grass, the surface temperature is lower on natural fields, reasonably thanks to the natural evaporation of the water always present in the ground in such quantities as to allow the life cycle of the grass. This condition cannot be successfully applied to a synthetic carpet since the quantity of water that can accumulate, without making it impracticable, is reduced, thus making the evaporation effect short-lived. Thermal variations probably also influence the overall friction coefficient of the surface. In fact, it must be remembered that polymers, with an increase in temperature, are characterized by the transition from a glassy-rubber phase to the so-called "glass transition temperature". This step implies a change in the mechanical properties (greater deformability/lesser stiffness and increase in energy dissipated/lesser energy returned by the soil). It is conceivable how - leaving aside the aspects linked to the ball/ground interaction - the surface temperatures detectable in a synthetic grass covering can significantly modify the grip of the shoe and, consequently, motor patterns and stability of the body (Lisi, 2016).

At this point, a further consideration is necessary. Professional tennis tournaments take place in numerous locations around the world and on different surfaces. It is not unusual for players to be forced to change playing fields in the space of one or two weeks, moving, for example, from clay court of Roland Garros, and other European tournaments, to grass courts like those of Queen's and the German Halle. These sudden changes, due to an increasingly busy competitive calendar, and the impossibility of adapting to this or that specific surface in such a short time, translate into a greater predisposition to traumatic injuries to the lower limbs. In fact, playing frequently on different surfaces can be associated with injuries to the lower limbs (Hutchinson et al., 1995; Safran et al., 1999; Alexander et al., 2022). More specifically, players who played on multiple surfaces had a higher prevalence of those overuse injuries, compared to those who played primarily on one court surface (Alexander et al., 2022). A key role in this respect is played by the foot.

Foot presents a very rich proprioception afferent to the central nervous system (CNS) capable of implementing automatic motor reflexes calibrated on the basis of previous experiences. Therefore, if by taking a jump the subject's brain unconsciously "predicts" a certain resistance of the ground, the nervous system automatically "pre-loads" those muscles and tendons (agonists and antagonists) best suited to the need, and with a tension adequate to the task. Obviously, if the aforementioned prediction turns out to be incorrect (see, for example, a grassy layer that is too soft), the agonist/antagonist balance become unbalanced with the consequence that the load ends up weighing on an unstable ankle. In this case sprains, ligament injuries and fractures are likely to occur (Lisi, 2016).

Amateur player does not seem to suffer much from superficial changes (Saal, 1996). As for clay, it is not particularly harmful as it absorbs blows better, cushions and requires a sliding step (Saal, 1996). while "composite" fields would transfer greater loads to the lower limbs and spine. As for grass, we know their shock absorption characteristics, but some authors consider them even worse than composite court (Saal, 1996). In this regard, it has been found that, compared to sports on clay and hard courts, trunk injuries are more common on grass courts (Kryger et al., 2015).

From the results of a study (von Salis-Soglio, 1979) it emerged that a small group (15 subjects) of expert players experienced pain in the back and in the lower limbs during the practice of tennis on hard surfaces. This painful symptomatology, however, was generally modest, if not completely absent, when the same players carried out their professional activity on clay courts.

Empirically gleaned information from Gieck (1979), along with his personal experiences with degenerative disc disease, indicates that softer surfaces, such as grass or clay, reduce the impact on the musculoskeletal system compared to hard surfaces, such as asphalt and concrete (Gieck, 1979).

Regardless of the playing surface, it must be evidenced the significant influence on the ball speed due to the change of material, rigidity, size and weight of the rackets.

Graphite rackets allow the player to transfer a higher momentum to the ball in comparison with those produced by wooden made rackets. Furthermore the first group allow to impact more spin to the ball (Miller & Cross, 2003). Graphite rackets are lighter and stiffer with a potential advantage for the player but the, as a whole, the game speed has dramatically increased on all the surfaces. Despite a scientific comparison is not available, it is reasonable to speculate that a stronger biomechanical body stress can be associated to the evolution of the rackets mainly due to speed and strategy of play.

Reflections and conclusions

Based on what has been explained so far, is it still preferable to practice the sport of tennis on a "soft", slow surface, such as the very common red clay? The answer seems to be yes, also because, from the results of research conducted on professional male tennis players, it can be seen that hard courts are characterized by a significant higher incidence of injuries compared to clay courts (Bastholt, 2000). It can be seen how, among the four different surfaces examined, the rate of lower limbs injuries on hard surfaces is higher than on clay (Alexander et al., 2022). On the other hand, if most tournaments in Europe are played on clay, tennis courts in America and the rest of the world are made of hard material (Table 3).

Table 3
Different court surfaces in the four most important tournaments in tennis (Grand Slam)

Grand Slam tournament	Type of court surfaces
Australian Open	Plexicushion Prestige hard courts
Roland Garros	Clay courts
Wimbledon	Grass courts
US Open	DecoTurf hard courts

Some author's investigation (O'Donoghue & Liddle, 1998; O'Donoghue & Ingram, 2001) focusing on side aspects of the mechanical properties of the surface, have shown how competition on clay can be an indirect cause of injuries due to the duration of the match itself and only partly attributable to the surface. On grass, where the matches have a shorter duration and the tennis player frequently uses descents to the net immediately after the serve ("serve and volley"), the different types of movement are likely to cause damage of varying degrees and intensity, but in this case referable more to the style of play than to the characteristics of the surface (O'Donoghue & Liddle, 1998; O'Donoghue & Ingram, 2001).

On turf, probably following muscle fatigue, the fibers most involved in a certain type of physical-motor activity become more difficult to recruit, so movement control is progressively less automatic and efficient. This exposes the player to the possibility of sudden and very violent contractions.

In the second case, the typical "serve & volley" techinique, involving continuous accelerations and stops, increase the risk of acute associated injuries (meniscus, ligaments), especially in those tennis players who do not have perfect control of the stability of the ankle, mainly on the coronal plane.

Compared with the other court surfaces, there was a higher prevalence of lower limb overuse injuries when playing on hard court (Pluim et al., 2018).

It is interesting, however, to table the results of the studies (Table 4) analyzed in the systematic review of Alexander et al. (2022).

Authors cited above (Alexander et al., 2022) recall how it has been established in the literature that compared to clay courts, hard courts are significantly more foreseeable, having higher grasp, higher hardness, and difficulty to slide on (Starbuck et al., 2015). High loading has been linked to hardcourts, especially on the lateral parts of the foot (Damm et al., 2014). Ankle inversion injuries have previously been linked to high degrees of inversion (Kristianslund et al., 2011).

Table 4
Summarises the percentage of the incidence of injuries in surfaces as reported in five different studies (Alexander et al., 2022)

Study	Incidence Rate	Surface the injury been reported
1	Total of 700 injuries occurred at a rate of 20.7%	Grass courts (throughout the competition season, switching between surfaces)
2	50% to 65% for men 60% and 70% for women	Hard, clay and grass courts
3	Less than 50%	Clay and grass courts
4	Men and women are respectively – 80%	Clay and hard courts
5	57% of the injured players	Clay and hard courts

In tennis, it is worth remembering that the potentially riskiest movements are the lateral movements in which the player stops abruptly to hit the ball.

In this particular situation the soles of the shoes can act as a lever pin, forcing the foot into supination and sometimes causing a trauma. A surface with high friction is more critical than clay: the latter, in fact, allowing a certain degree of sliding, leaves the player sufficient time to actively control the movement. This assertion is scientifically supported by the values of the maximum rotation moment, measured with a dynamometric platform in 12 subjects who wore different shoes. The result obtained appears extremely interesting: the variability of the maximum moment found on the different surfaces is much greater (approximately 100%) compared to that found between the different shoes (Nigg, 1978).

The latter data suggest that the mechanical properties of the surface produce greater variations in joint load compared to footwear. It can therefore be stated that, regardless of the type of footwear, it is the playing field that determines the stresses imposed on the musculoskeletal system (Lisi, 2016). Among other things, another difference between clay and concrete is a greater angle of inversion of the ankle during stance (Damm et al., 2013). The results showed that hard courts required treatment for injuries much more frequently than clay courts during matches (Damm et al., 2013).

We agree with some authors (Alexander et al., 2022) who underline that trunk injuries (more frequent than on clay or concrete surfaces) are attributable to the fact playing on the quicker surface of grass, with a smaller ball bounce and shorter point length, may significantly affect patterns of injury because there is a potential risk of injury when moving from clay to grass.

We have already had the opportunity to remember how the transition from clay to grass occurs in a very short time, without the necessary gradualness (Lisi, 2016). Suffice it to say that, in ATP and WTA 2024 calendar (Table 5 & Table 6), Roland Garros starts at the end of May and ends at the beginning of June (May 26 - June 9), while the first grass tournaments start the day after the Paris tournament. In the 2024 tennis season, the situation became even more complicated as the Olympic Games took place (Paris, 26 July - 11 August) and, for some of the strongest tennis players, the 6 Kings Slam, a tennis exhibition tournament which took place in Riyadh (Saudi Arabia, 16-19 October).

Table 5
The busy calendar of GS* and ATP tournaments limited to the May-July 2024 period

Start date	ATP Tournament	Location and surface
May 26	**Roland Garros**	**Paris, clay**
June 10	Libéma Open	s-Hertogenbosch, grass
June 10	Boss Open	Stuttgart, grass
June 17	Terra Wortman Open	Halle, grass
June 17	Cinch Championships	London, grass
June 23	Mallorca Championships	Mallorca, grass
June 24	Rothesay International	Eastbourne, grass
July 1	**Wimbledon**	**Great Britain, grass**
July 15	Hamburg European Open	Hamburg, clay
July 15	Nordea Open	Bastad, clay
July 15	EFG Swiss Open	Gstaad, clay
July 15	Infosys Hall of Fame Open	Newport, grass
July 22	Atlanta Open	Atlanta, hard
July 22	Generali Open	Kitzbuhel, clay
July 22	Plava Laguna	Umag, clay
July 26	**Olympic Games**	**Paris, clay**
July 29	Citi Open	Washington, hard

* GS: Grand Slam

Table 6
The busy calendar of GS* and WTA tournaments limited to the May-July 2024 period

Start date	WTA Tournament	Location and surface
May 26	**Roland Garros**	**Paris, clay**
June 10	Libéma Open	s-Hertogenbosch, grass
June 10	Rothesay Open	Nottingham, grass
June 10	BBVAOpen	Valencia, clay
June 17	Rothesay Classic	Birmingham, grass
June 17	ecotrans Ladies Open	Berlin, grass
June 17	Veneto Open	Gaiba, clay
June 23	Bad Homburg Open	Bad Homburg, grass
June 24	Rothesay International	Eastbourne, grass
July 1	**Wimbledon**	**Great Britain, grass**
July 8	Nordea Open, Bastad	Bastad, clay
July 8	Grand Est Open 88	Contrexeville, clay
July 15	Ladies Open	Palermo, clay
July 15	Hungarian Grand Prix	Budapest, clay
July 21	Livesport Prague Open	Prague, clay
July 21	Unicredit Iasi Open	Iasi, clay
July 22	Polish Open	Warsaw, hard
July 26	**Olympic Games**	**Paris, clay**
July 29	Mubadala City DC Open	Washington, hard

* GS: Grand Slam

We once again reiterate the opportunity to modify the ATP and WTA calendar in consideration also of the recent complaints of the protagonists of the tour. During the Cincinnati 2024 tournament, one of the strongest WTA tennis players asked for a reduction in the tennis calendar in an interview with Sky Sports (Dimon, 2024). During the seventh edition of the Laver Cup (Berlin, September 20-22), a four-time Grand Slam singles winner has criticised the congested ATP tennis calendar (Fonseca, 2024).

Conflict of interests

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