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# JUMPS AND LOWER LIMB STRENGTH ASYMMETRY IN YOUNG SOCCER PLAYERS: DIFFERENCES BETWEEN SAND AND CONVENTIONAL SURFACES

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**Abstract**

**Study purpose.** The aim of the study was to evaluate jumping performance and lower limbs strength asymmetry in young soccer players by comparing this movement performed on both a conventional surface and a sand surface.

**Materials and methods.** 20 young soccer players under 17 years old randomly performed a standing long jump, a single hop jump in the sagittal plane (Hop Jump Test) and a single side hop jump in the frontal plane (Side Hop Jump Test), first on a conventional surface (natural grass) and then on sand. The jump distance and strength asymmetry was calculated using the formula: (NDL / DL) x 100.

**Results.** The values from the two different jumping conditions showed a statistically significant decrease in the Broad Jump Test ($p<0.001$, ES: 3.56), Hop Jump Test left limb ($p<0.001$, ES: 4.99), Hop Jump Test right limb ($p<0.001$, ES: 3.95), Side Hop Jump Test left limb ($p<0.001$, ES: 4.67) and Side Hop Jump Test right limb ($p<0.001$, ES: 2.98) in the sand condition.

The asymmetry values in the Hop Jump Test and the Side Hop Jump Test showed a statistically significant increase (+21.5%, $p<0.001$, ES: 3.66 and +41.1%, $p<0.001$, ES: 1.99, respectively) when comparing the performance on grass and sand.

**Conclusions.** This different performance response in the two different jumping modes leads to the hypothesis that young soccer players who want to stress their explosive strength ability and joint stability should favor the use of one-leg rather than two-leg jumps.

The values described in the study lead to the hypothesis that training on sand should be suggested when the young soccer player presents modest values of inter-limb asymmetry measured on a conventional surface.

**Keywords:** sand, jump, inter-limb asymmetry, young soccer player, soccer.

## Introduction

Training makes use of a variety of equipment and surfaces in an attempt to stimulate the athlete's neuromuscular apparatus in an increasingly specific manner.

In a particular way, soccer training at both youth and professional levels tries to make use of new motor tasks and new strategies to prepare the athlete, whether young or advanced, in a way that is increasingly adapted to the demands of the performance model.

Training, therefore, over the years has proposed multiple ways of performing general and specific exercises in order to identify strategies and methodologies capable of returning the best performance benefits, perhaps reducing the injury risk.

The increasing diffusion of sports disciplines very similar to football (futsal and beach soccer in the first instance) and the spread of playing surfaces of different nature (artificial vs. natural, artificial of different and latest generation) have highlighted the need to investigate the role that these play in the realisation of the performance (Gould et al., 2023; López-Fernández et al., 2018; Williams et al., 2011), load and skills associated with the sport (Strutzenberger et al, 2022; Kuitunen et al., 2023; Xiao et al., 2022).

Notably, the sandy surface, in the face of widespread and widespread use in both rehabilitation courses and specific training sessions (Rago et al., 2018; Pereira et al., 2023), is

only recently gaining research attention in soccer (Cetolin et al., 2021; Larsen et al., 2021; Costa et al., 2022).

An interesting review on the use of different training grounds in soccer reveals a heterogeneity of surfaces that determine specific functional adaptations in the soccer players (Rago et al., 2018).

Just as it emerges that surfaces with greater compliance, such as sand, return adaptations in the lower limb strength ability (de Lira et al., 2017).

In the case of sand, it is evident in the literature that energy expenditure (Zamparo et al., 1992; Pinnington & Dawson, 2001a & 2001b), as well as the response of maximal oxygen consumption, peak heart rate value, exertion perception and lactate, are significantly higher when analysing high and very high intensity exercise (Cetolin et al., 2021).

Initially, the focus of research on understanding the different energy expenditure between more conventional and sandy surfaces arose years ago for military purposes; conversely, today, the increase in the sporting qualification of some athletes and sports disciplines practised on sand has also begun to call for more scientific speculation for other activities and skills other than walking or running (Binnie et al., 2014; Gaudino et al., 2013).

This is the case for sports that, although practised on sand, require high performance demands in jumping skills (Ahmadi et al., 2021; Larsen et al., 2021; Leite, 2021). It is evident that the surface on which the performance is required is capable of altering the biomechanics of the jump (Pereira et al., 2021 & 2022; Binnie et al., 2014; Riggs & Shepppard, 2009), inducing substantial differences whether this movement is performed on sand or on a hard or conventional surface (Giatsis et al., 2004 & 2022; Riggs & Sheppard, 2009).

In this regard, it emerges that the lower performance values in sand jumping performances are attributable to a lower reuse of elastic energy and foot slippage (Binnie et al., 2014; Impellizzeri et al., 2008).

Furthermore, when observing the drop jump execution, there is evidence that confirms the energy-dissipating role of the sandy surface: in comparison to a hard surface, there is a significantly lower jump height, ground reaction force, peak power and peak angular velocity at the ankle; furthermore, a higher rate of force development is observed, as is a higher knee bend angle (Giatsis et al., 2022).

With regard to run performance, previous studies have found that on sand, the energy cost of a low-speed run is 24% higher than on a conventional surface (Zamparo et al., 1992).

Again, the specificity of sand has been described in observation in the biomechanics of high-intensity running and the energy cost of this type of performance: the results obtained by some researchers show, that on sand it is possible to perform maximal intensity sprints with higher energy expenditure and metabolic power values, without reaching maximum speed observed in maximal sprint test but with smaller impact shocks (Gaudino et al., 2013). Furthermore, exercises with change of direction carried out on this surface allow to reach higher deceleration values (Gaudino et al., 2013).

Ultimately, the compliance of sand attenuates and significantly reduces the efficiency of the mechanisms involved in the optimisation of performances that require elastic reuse, whether they are jumps or rapid movements that rely on the stretch-shortening cycle as in sprint running, however, they determine a lower load in the ground contact phase (Giatsis et al., 2022).

This disadvantageous picture seems to be determined by the characteristics of sand: it differs from other types of surfaces in that the presence of air gaps means that the surface is displaced and compressed during footstrike or propulsive thrust (Gaudino et al., 2013).

Consequently, the foot slips and sinks, forcing the lower limb muscles to carry out additional work to stabilize the point of reaction force on the surface (Sanchez-Sanchez et al., 2020; Gaudino et al., 2013; Lejeune et al., 1998).

In the literature, however, there remains more than one open question: whether certain skills on sand, a surface that, in addition to dissipating elastic energy, is extremely unstable compared to more conventional ones, may represent a potential risk factor for the joints of the lower limb.

Furthermore, the behaviour of young athletes on a surface with such peculiar characteristics has been neglected, directing attention predominantly to adult or highly qualified athletes (Ahmadi et al., 2021; Cetolin et al., 2021).

The aim of the study is to evaluate jumping performance and lower limbs strength asymmetry by comparing this movement performed on both a conventional surface and a sand surface in young soccer players.

## Materials and methods

### *Study participants*

20 young soccer players under 17 years-old were recruited to participate voluntarily in this study (mean ± SD; age: 16.6±0.3; height: 1.79 ± 0.12; body mass: 67.9±4.7; body mass index: 21.48 ± 1.36). The study was carried out in Olimpic Center of Comitato Olimpico Nazionale Italiano (C.O.N.I.).

Prior to the start of this investigation, all young soccer players were fully informed about the testing and warm-up's procedures and a written informed consent was obtained from the participants or their legal tutors before data collection.

Before participants recruitment, the study was approved by the Apulian Regional Ethics Committee of the F.I.G.C. Additionally, the research design and procedures complied with the standards set out in the Declaration of Helsinki.

### *Study organization*

During the week before data colelction tests, one familiarization session was performed to to know the test protocol and execution technique.

Each participant performed an approximately 15-minute warm-up consisting of 5 minutes of moderate intensity running (at~ 60% maximal heart rate and self-assessed), 5 minutes of dynamic stretching and mobility of the lower limbs, and 5 minutes of acceleration and deceleration, high knee running, bouncing, reactive pogo jumping and two near-maximal attempts of each test.

The tests were performed randomly by each participant both on sand and on a conventional surface (natural grass).

In particular, they performed a standing long jump, a single hop jump in the sagittal plane (hop jump test) and a single side hop jump in the frontal plane (side hop jump

test), first on a conventional surface (natural grass) and then on sand.

The lower limb strength asymmetry was calculated using the formula: (NDL / DL) x 100 (Ceroni et al., 2012; Bishop et al., 2016).

### *Statistical analysis*

Descriptive statistics (mean ± standard deviation) were performed for the data analisys. One-way analisys of variance (ANOVA) was used to determine within-group comparisons (conventional vs sand condition). For the differences between the averages that were significant, Cohen's d was used to check the effect size index (Effect Size, ES). As for the effect size index, after calculating the δ index it is possible to convert it into Effect Size: ≤ 0.20 small; 0.50 average; ≥ 0.80 large. All statistical analyses were performed using SPSS software, version 22.0 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at $p < 0.05$.

## Results

The values from the two different jumping conditions showed a statistically significant decrease in the Broad Jump Test (224.1±14.9 cm vs 171.1±14.8cm, $F_{(1,38)}$=126,743, p<0.001, ES:3.56), Hop Jump Test left limb (186.5±12.8 cm vs 124.3±12.1 cm, $F_{(1,38)}$=287,376, p<0.001, ES:4.99), Hop Jump Test right limb (194.9±13.3 cm vs 142.1±13.4 cm, $F_{(1,38)}$= 134,980, p<0.001, ES:3.95), Side Jump Test left limb (161.5±12.9 cm vs 110.2±8.6 cm, $F_{(1,38)}$=219,919, p<0.001, ES:4.67) and Side Jump Test right limb (169.2±15.3 cm vs 129.3±11.1 cm, $F_{(1,38)}$=80,142, p<0.001, ES:2.98) in the sand condition.

The asymmetry values in the Hop Jump Test and the Side Jump Test showed a statistically significant increase (respectly, +21.5%, $F_{(1,38)}$=40,408, p<0.001, ES:3.66 and +41.1%, $F_{(1,38)}$=27,453, p<0.001, ES:1.99) when comparing the performance on grass and sand.

All values are summarised in the table 1.

## Discussion

The aim of the study was to compare the values of jumping, two-legs jump and one-leg jump, and lower limb functional asymmetry values, performed on a conventional surface and on sand.

The issue of the use of different surfaces in the soccer's training is of topical relevance, as much for the performance-enhancing aspects as for the reduction of the injury risk.

In particular, this appears to be the first analysis of the jumping performance of young soccer players on sand and grass in order to understand performance differences and information regarding the injury risk reduction.

The percentage decreases achieved in both two-legs jumping and one-leg jumping performances are significantly higher than what has been identified in the literature with over 18-years-old beach soccer palyers of both genders, in which this difference stopped at approximately 16.7% (Larsen et al., 2021).

This value, which differs from what has been found in the literature, would lead one to assume two types of considerations: there could be a particular adaptation phenomenon in those who habitually perform on sand, such that they are able to 'compensate' for the biomechanical disadvantage resulting from the sandy surface; on the other hand, one could hypothesise a greater performance discomfort in young elite athletes and women than in highly qualified athletes.

From a methodological and organisational point of view, therefore, the sandy surface seems to lend itself effectively to the neuromuscular training of the young athlete as it appears to represent an adequate overload.

One-leg jumping values show greater performance decrements than two-legs jumping performances: probably a greater stability determined by the two-legs start allows for the expression of greater levels of explosive force.

This different performance response in the two different jump modes leads to the hypothesis that young soccer players who want to stress the explosive strength ability and joint stability should lean towards using one-leg jumps rather than two-legs jumps.

If this performance disadvantage on sand is substantially already described in the literature, especially with over 18 years-old atheletes or highly qualified athletes, the new finding of this study is inherent in the strength asymmetry values found in young soccer players.

Lower limbs functional asymmetries are determined by strength deficits between the two limbs (Read et al., 2021; Loturco et al., 2019; Sannicandro et al., 2014) and differ from muscular imbalances, which represent an alteration in the strength relationship between agonist and antagonist muscles (Sannicandro et al., 2014).

**Table 1.** Jump and inter-limb asymmetry values obtained in evaluations

| Indicator | Grass/conventional surface (X±SD) | Sand (X±SD) | Difference % | p | Cohen's d |
|---|---|---|---|---|---|
| Broad Jump (cm) | 224.1± 14.9 | 171.1±14.8 | -23.7 | 0.001 | 3.56 |
| Hop Jump Test left (cm) | 186.5±12.8 | 124.3±12.1 | -33.4 | 0.001 | 4.99 |
| Hop Jump Test right (cm) | 194.9±13.3 | 142.1±13.4 | -27.1 | 0.001 | 3.95 |
| Asymmetry Hop Jump Test (%) | 6.2±2.7 | 16.1±6.3 | 21.5 | 0.001 | 3.66 |
| Side Jump Test left (cm) | 161.5±12.9 | 110.2 ± 8.6 | -21.8 | 0.001 | 4.67 |
| Side Jump Test right (cm) | 169.2±15.3 | 129.3±11.1 | -23.5 | 0.001 | 2.98 |
| Asymmetry Side Jump Test (%) | 6.9±3.3 | 14.1±3.9 | 41.0 ±1 | 0.001 | 1.99 |

Lower limb functional asymmetry has recently been the subject of numerous investigations concerning many sports (Filter et al., 2021; Rutkowska-Kucharska, 2020), including contact sports, limited-contact (Impellizzeri et al., 2007) and non-contact sports aimed at understanding the role of conditioning in performance (Madruga-Parera et al., 2020a & 2020b) and injury prevention (Bishop et al., 2017 & 2018; Markovic et al., 2021).

This factor becomes relevant in soccer performance because the game requires very high intensity actions performed unilaterally by the single lower limb (Helme et al., 2021): kicking, deceleration, jumping to hit the ball with the head, etc. are all unilateral skills (Raya-González et al., 2021; Keiner et al., 2021).

This asymmetry appears to significantly influence performance (Madruga-Parera et al., 2020a & 2020b; Filter et al., 2021) but more importantly it appears to be a injury risk factor when it exceeds the 10% or 15% cut-off value (Keiner et al., 2021; Carvalho et al., 2016; Fort-Vanmeerhaeghe et al., 2016).

It is precisely to this cut-off value that the data observed in the hop test and the side hop test with regard to the asymmetry parameter must direct the greatest attention (Raya-González et al., 2021; Keiner et al., 2021): the average asymmetry value of the hop shows an increase of around 21%, while that of the side hop reaches an increase of over 40% in the grass-sand comparison.

Another interesting consideration concerns the asymmetry values themselves, which exceed the cut-off of 10% and verge on that of 15%, presenting a significant variability within them, probably indicating a significant diversity of the sample's performance within itself.

The considerations inherent in this value, on the one hand, would suggest that this surface exalts the lower limb strength asymmetry to an even greater extent than grass; while on the other hand, they must lead to some reflections on the preventive evaluations that should be conducted before exploiting the performance advantages derived from the use of the sandy surface; especially if the staff intends to make use of sport-specific exercises that increase the frequency of contact or are carried out in a situational context.

Analytical tasks performed on unstable or reduced surfaces (i.e. also on a single limb), can be incorporated into a training plan as part of an injury prevention strategy.

An unstable surface imposes an effort on the neuromuscular system to stabilise the joints involved in the execution of the movement. All of the beneficial effects of movements performed on unstable surfaces are transferred into sport-specific performance; for example, in soccer, the correct activation of the core muscles achieved during the execution of balance training exercises is a good example of the positive transfers that can be achieved when performing sport-specific movements (Behm et al., 2010; Behm & Anderson, 2006).

The same considerations can be made for stabilisation tasks aimed at the joints of the lower limb with an internal or external focus (Ghanati et al., 2022; Sherwood et al., 2020).

Therefore, not only the type of exercise but also the duration of training loads on sand must be carefully considered to prevent fatigue from increasing the interlimb asymmetry value (Guan et al., 2021; Wrona et al., 2023).

A further prospect of this research could involve analysing the number of jumps or runs on sand that increase the asymmetry value, thus putting the young soccer player at injury risk.

Furthermore, further studies could compare what emerges with young male footballers with what occurs with young female footballers, who present a gender-specific risk of injury.

## Conclusions

In conclusion, the sandy surface requires further investigation in order to understand which volumes may prove effective for performance enhancement, as has been amply demonstrated in the literature, and which training loads, on the contrary, may predispose to the risk of non-contact injury due to the instability determined by the characteristics of the surface itself.

This aspect is to be considered not so much for the presentation of analytical tasks that allow the activation of an internal focus during execution, but rather for the use of sport-specific exercises with the ball apparatus that, on the contrary, see the external focus prevail.

It remains to be understood whether, following prolonged periods of training on sand, phenomena of adaptation to the surface can occur and be observed that reduce the instability caused by the sand itself.

For these reasons, it is hoped that subsequent analyses may involve samples of athletes, young or highly qualified, who can be monitored and evaluated before undertaking sand training and at the end of it.

## Conflict of interest

The authors declare no conflict of interest

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# АСИМЕТРІЯ СТРИБКІВ І СИЛИ НИЖНІХ КІНЦІВОК У МОЛОДИХ ФУТБОЛІСТІВ: ВІДМІННОСТІ МІЖ ПІЩАНОЮ ТА ТРАДИЦІЙНОЮ ПОВЕРХНЯМИ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 1 табл., 6 рис., 51 джерело.

**Мета дослідження.** Метою дослідження було проведення оцінки асиметрії результативності стрибків та сили нижніх кінцівок у молодих футболістів шляхом порівняння виконання цього руху на традиційній поверхні та на піщаній поверхні.

**Матеріали та методи.** 20 молодих футболістів віком до 17 років випадковим чином виконували стрибок у довжину з місця, один стрибок на одній нозі вперед у сагітальній площині (тест на стрибок на одній нозі вперед) та один стрибок на одній нозі вбік у фронтальній площині (тест на стрибок на одній нозі вбік), спочатку на традиційній поверхні (натуральна трава), а потім на піску. Асиметрію дистанції стрибків і сили обчислювали за формулою: (NDL (недомінантна нога) / DL (домінантна нога)) x 100.

**Результати.** Значення, одержані в цих двох різних режимах стрибків, показали статистично значуще зменшення в тесті на стрибок у довжину з місця ($p<0,001$, ES (розмір ефекту): 3,56), тесті на стрибок на одній нозі вперед – ліва нога ($p<0,001$, ES (розмір ефекту): 4,99), тесті на стрибок на одній нозі вперед – права нога ($p<0,001$, ES (розмір ефекту): 3,95), тесті на стрибок на одній нозі вбік – ліва нога ($p<0,001$, ES (розмір ефекту): 4,67) та тесті на стрибок на одній нозі вбік – права нога ($p<0,001$, ES (розмір ефекту): 2,98) у режимі виконання стрибків на піску.

Під час порівняння результативності на траві та на піску значення асиметрії в тесті на стрибок на одній нозі вперед і в тесті на стрибок на одній нозі вбік показали статистично значуще збільшення (+21,5%, $p<0,001$, ES (розмір ефекту): 3,66 та +41,1%, $p<0,001$, ES (розмір ефекту): 1,99 відповідно).

**Висновки.** Цей різний ефект у показниках результативності в двох різних режимах виконання стрибків дає підстави для гіпотези, що молодим футболістам, які бажають піддати напрузі свою здатність до вибухової сили та міцність суглобів, слід віддавати перевагу використанню стрибків на одній нозі, а не на двох ногах.

Значення, описані в дослідженні, дають підстави для гіпотези, що тренування на піску слід рекомендувати, коли молодий футболіст демонструє невеликі значення асиметрії між кінцівками за результатами вимірювання на традиційній поверхні.

**Ключові слова:** пісок, стрибок, асиметрія між кінцівками, молодий футболіст, футбол.

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