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EFFECTS OF DIFFERENT SPORT SURFACES ON MUSCLE PERFORMANCE

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Abstract. The aim of the present study was to examine the effects of different sport surfaces on athletic performance by means of muscle performance. Twenty two elite male basketball players, aged between 17 and 28, participated in this study. This study was executed on 7 different sport surfaces: asphalt, synthetic grass, natural grass, tile powder, soil, wooden parquet and EPDM (Ethylene Propylene Diene Monomer). Leg strength (LS) and vertical jumping height (VJH) were measured at rest and after a given training protocol on each surface. Surface compliance was evaluated with a drop test using a medicine ball. Asphalt and synthetic grass were the most fatiguing, natural grass, soil and tile powder were moderately fatiguing, parquet and EPDM were the least fatiguing surfaces. The results of surface compliance were inconsistent with those obtained in LS and VJH tests. As the compliance of the surface increased LS and VJH increased, i.e. performance was decreased. The results of the present study suggest that it is better to use parquet and EPDM in construction of indoor sport surfaces. On the other hand, it may be appropriate to build outdoor surfaces with natural grass because of its aesthetic and visual impacts and its contribution to the amount of urban green area.

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Introduction

Today, humans living in big cities need recreation in order to regain physical and spiritual energy after an intense daily working. Sport is one of the most favourable recreational activities. If one participates in his sport longer, he will get

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rid of his stress quicker. The duration of exercise is inversely related to muscle performance.

There are different kinds of surfaces on which the subjects play sports, e.g. natural grass, asphalt and wooden parquet. Besides, synthetic surfaces for sport and recreational usage have been manufactured. One of the important aspects in construction of sport surfaces is to improve athletic performance [4,14,30]. It has been suggested that the main feature of a sport surface that can affect the athletic performance is to storage and return energy [4,14] have argued that if some of the energy that an athlete requires for each step, stride, jump, landing, etc. can be reused, through energy return from the surface, the athlete can perform the same movement more efficiently. In other words, one can achieve a given physical activity by using less energy and, therefore, he continues his activity during a longer period.

Several studies have revealed a relationship between the compliance of the sport surface and performance. The analytic model of McMahon and Greene [31] has predicted a slight speed enhancement on tracks of intermediate compliance by comparison with running on a hard surface. Kerdok *et al.* [26] have postulated that an increased energy rebound from the compliant surfaces contributes to the enhanced running economy. It has been also reported that the reuse of elastic energy increases the muscular work efficiency in jumping [6].

If there is a relationship, whether it is positive or negative, between surface compliance and sport performance, the same relationship is expected to exist between surface compliance and muscle performance. That is to say, the effect of a given training programme on muscle performance will be different on surfaces having distinct compliance.

According to the authors' knowledge, a noticeable feature of the existant studies in the literature, except few [15,39], is that they deal with experimental surfaces not with real sport surfaces. The aim of the present study was to search the effects of different real sport surfaces on athletic performance by means of muscle performance and, therefore, to determine the most appropriate material(s) in building of sport surfaces.

Materials and Methods

Subjects: Twenty two elite male basketball players, aged between 17 and 28, participated in this study. Subjects volunteered to participate in this study after they had been fully informed of the nature of the test and of the associated risks in agreement with the recommendations of the local Ethics Committee.

Procedure

General: This study was executed on 7 different sport surfaces: asphalt, synthetic grass, natural grass tile powder, soil, wooden parquet and EPDM. Leg strength (LS) and vertical jumping height (VJH) were measured at rest twice, and the greater value was taken for further analyses. The same measurements were made after a given training protocol (described below) on 7 different sport surfaces, on separate days for each surface. The procedure was repeated once again on separate days for all surfaces. Then, the mean values calculated for each surface.

The subjects were asked to avoid vigorous activities for 24 h before each test, to have a good sleep, to consume same foods in the mornings of the test days, and to wear the same sportswear and shoes on all surfaces.

Training protocol: At the beginning, participants were given the opportunity to warm up with a running exercise at a tempo that they ran 800 m in 5 min. Then they carried out following exercises in indicated order:

1) A 10-minute shuttle run (20 m x 100 times; completed by all the subjects in equal time, i.e. in 10 minutes)

2) A 25-m sprint run with maximal effort (repeated 5 times)

3) A double-leg hop test [jumping onto a gymnastic table that was 60 cm in height and landing on the surface consecutively along 5 tables arranged in a row (Fig. 1); repeated 5 times]

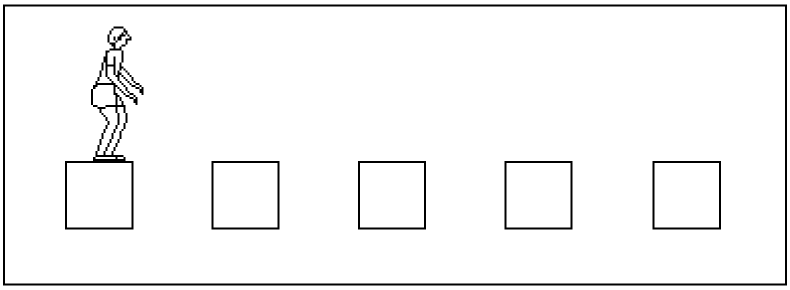

Fig. 1
Double-leg hop test

Measurements

Leg strength (LS): Back/leg dynamometer (Takei Kiki Kogyo, Japan) was used to measure leg strength. After familiarization with the test, the subject stood on a platform with their feet apart at a comfortable distance of shoulder width for balance. Their hands grasped each end of a bar. The subject was asked to flex at their knees to approximately 110 degrees. The back was kept straight and the hips were positioned directly over the ankle joints. In this way, the activation of back muscles was eliminated. The chest was kept forward and the head was held in an erected position. The subject took in a large breath and slowly exhaled as they attempted to extend their knees smoothly and as forcefully as possible. LS was expressed as kilogram.

Vertical jumping height (VJH): The vertical jumping test consisted of leg flexion from the standing position immediately followed by a maximal jump with the hands free. These jump test were monitored with a digital jump meter (Takei Kiki Kogyo, Japan), which recorded the jump height.

Surface compliance: A medicine ball weighing 5 kilograms, which is filled with air and, thus, bouncing, was used to assess the surface compliance. The ball was let to drop freely from the height of one meter near a meter which was vertically positioned on the floor (100 cm in length). This process was recorded by a video camera. The highest point that the bottom of the bounced ball reached after hitting on the surface was determined in slow motion by means of the meter in the image on the camera screen. The measurement was repeated 35 times for each surface, each time on a different place of the measured surface.

Statistics: Ordinary statistical methods including means and standard deviations were used. Differences between mean values were tested for significance by the one-way ANOVA and Post Hoc LSD test.

Results

The mean values of leg strength and vertical jumping height, obtained at rest and on 7 different sport surfaces were presented in Table 1.

Analysis of variance showed significant differences among surfaces in terms of leg strength ($F=5.72$; $P<0.001$) and vertical jumping height ($F=15.03$; $P<0.001$). Post hoc test of LSD revealed that the rest values for LS and VJH were significantly higher than those obtained after training on all surfaces, except LS on parquet although the difference was great ($P<0.05$). These findings show that the training programme was fatiguing.

The mean LS and VJH measured on asphalt were lower than those measured on the other surfaces, except LS on synthetic grass and tile powder, and VJH on synthetic grass ($P<0.05$).

Table 1
The leg strengths and vertical jumping distances [mean (SD)] obtained at rest and on different sport surfaces after training (n=22)

		Leg strength (kg)	Vertical jumping height (cm)
At rest		180.6* (25.9)	72.7* (8.1)
After training	Parquet	166.6 (23.9)	67.0 (7.6)
	EPDM	162.5 (24.8)	65.0 (7.1)
	Natural grass	159.0 (24.0)	64.4 (7.4)
	Soil	155.5 (23.2)	61.5§ (6.7)
	Tile powder	151.8† (22.3)	60.5‖ (6.8)
	Synthetic grass	145.8‡ (20.1)	57.9‖ (5.4)
	Asphalt	141.4 (18.3)	54.6# (5.1)
	F	6.43	15.03

*significantly different from all the others (for parquet and EPDM, P<0.05; for the rest, P<0.001); †significantly different from parquet (P<0.05); ‡significantly different from parquet (P<0.005) and EPDM (P<0.05); ¶significantly different from parquet (P<0.001), EPDM (P<0.005), natural grass (P<0.05) and soil (P<0.05); §significantly different from parquet (P<0.01); ‖significantly different from parquet and EPDM (for both, P<0.005); #significantly different from all the others except synthetic grass (for tile powder, P<0.01; for the rest, P<0.001)

The mean LS (not for soil) and VJH recorded on parquet were greater as compared to those noted on tile powder, synthetic grass and soil (P<0.05). The mean LS and VJH achieved on EPDM were higher than those obtained on synthetic grass, and on tile powder and synthetic grass, respectively (P<0.05). The mean VJH measured on natural grass was higher than that obtained on synthetic grass (P<0.05).

Table 2 shows the bouncing heights of a given ball that was let to free drop from a constant level on examined surfaces. According to these results, the seven surface were arranged, from the stiffest to the softest, as follows: asphalt, synthetic grass, tile powder, soil, EPDM, parquet and natural grass.

Table 2
Bouncing height of the ball on different sport surfaces [mean (SD)]

	Parquet	EPDM	Natural grass	Soil	Tile powder	Synthetic grass	Asphalt
Bouncing height of the ball (cm)	49.1 (0.7)	50.6 (0.8)	44.9 (0.8)	51.5 (0.9)	52.3 (0.8)	54.2 (0.7)	60.1 (0.5)

All values are significantly different from each others ($P<0.001$).

Discussion

The purpose of this paper was to investigate the effect of different sport surfaces on muscle performance by means of leg strength and vertical jumping height after a given training programme. In the present study, the mean LS and VJH values before training were significantly higher than those obtained on all surfaces after training. These findings showed that the training programme was fatiguing.

The mean LS (not for tile powder) and VJH obtained on asphalt were significantly lower than those obtained on all other surfaces, except synthetic grass. Synthetic grass had lower mean LS and VJH values compared to parquet, EPDM and natural grass, except LS of natural grass. In addition to these findings, if the lower mean LS and VJH values of synthetic grass compared with those of tile powder and soil, although they were not statistically significant, are taken into consideration, asphalt and synthetic grass were the most fatiguing surfaces.

On the other hand, parquet and EPDM were the least fatiguing surfaces. The mean LS and VJH achieved on parquet were significantly higher from those recorded on asphalt, tile powder, synthetic grass and soil, except LS for soil. EPDM had greater mean LS (not for tile powder) and VJH values compared with asphalt, synthetic grass and tile powder. Although they were not statistically significant, asphalt had higher mean LS and VJH values than natural grass, and EPDM had higher mean LS and VJH values than natural grass and soil.

Natural grass, soil and tile powder were moderately fatiguing surfaces. Because the mean LH (not for tile powder) and VJH values achieved on these three surfaces were significantly greater than only those obtained on asphalt and, only for VJH of natural grass, synthetic grass.

If a surface is less fatiguing, one can achieve a given training programme on that surface with less oxygen consumption compared with a more fatiguing one, i.e. sport surfaces affect athletic performance. The most important characteristic of a sport surface which may be related to performance seems to be its compliance. A person increases his leg stiffness (the stiffness of the integrated musculoskeletal system that behaves as a single linear spring during locomotion) when he is running or hopping on a compliant surface compared with running or hopping on a hard one [6,21,22,26,32,33]. Similarly, Daniel *et al.* [13] have reported that runners adjust leg stiffness for their first step on a new running surface. They found a %29 decrease in leg stiffness between the last step on a soft surface and the first step on a hard surface (from 10.7 kN m^{-1} to 7.6 kN m^{-1}, respectively). On the other hand, Tillman *et al.* [39] have found that the kind of surface have no significant effect on lower extremity kinematics in running. The results of a recent study have also suggested that it is not possible to generalize the effects of sports surfaces on lower extremity kinematics [15]. At least for Tilmann et al's study, a possible reason of this inconsistency is the relative similarity in hardness of the surfaces used in that study.

The majority of the studies have revealed that an increase in leg stiffness enhances running speed [7-9,20,27] or jumping performance [1-3,8,16,18,19]. Leg stiffness was also found to be associated with running economy, as measured by oxygen consumption, [17,26,30]. McMahon *et al.* [30] have reported that running with increased knee flexion (Groucho running) requires an increase of as much as 50% in the rate of oxygen consumption compared to normal running with greater leg stiffness. In another study, it has been concluded that non-pathological musculoskeletal tightness was associated with a decreased steady-state VO2 for treadmill walking and jogging [23]. Similarly, in a recent study the greater energy cost during running compared to the energy cost during walking was explained by the use of more flexed knee joint during running versus walking [5].

On the other hand, some investigators have found no relationship between leg stiffness and aerobic demand [25] or jumping and running performance [36]. In one study, a relationship has been found between the leg stiffness and the energy cost of running only in one subject who consumed less oxygen when he could maintain his stiffness [12]. All participants in the one-leg jump task were found to decrease their leg stiffness by about 15% when imposed height changed from 55 to 95% [28]. These contradictions can be explained by the style of the tasks performed [28], the difference in running speed, and the difference in surfaces selected. Indeed, the results of Farley et al's [19] study have indicated an increase in leg stiffness with increase in hopping height in the two-leg jump.

The increased stiffness of the leg spring on compliant surfaces may lead to a lower energetic cost compared with hopping or running on hard surfaces. The results of Kerdok et al.'s study [26] have suggested that the spring stiffness of the leg is progressively increased and that the metabolic cost of running is progressively reduced as surface stiffness is decreased from 945.7 to 75.4 kN/m. Arampatzis *et al.* [1,2] have suggested that an increase in leg stiffness causes an increase in the energy transmitted to and recovered from the sprung surface and simultaneously a decrease in the energy produced by the subjects.

In the present study, the results of the drop test showed that the hardest surface was asphalt. This finding is in consistent with the previous ones [31]. Unpublished energy return values quantified with drop tests (material testing using a shot) provided values between 40 and 70% for athletic surfaces and close to 0% for asphalt [4]. The order of the other surfaces used in this study was, from hardest to most compliant, as follows: synthetic grass, tile powder, soil, EPDM, parquet and natural grass. These data are in consistent with the results of LS and VJH except for natural grass which had the lowest bouncing height although it was not the least but a moderately fatiguing surface. This inconsistency can be explained by the energy dissipating nature of natural grass instead of its compliance. Therefore, if we rule out natural grass, the most compliant surface was wooden parquet. This kind of surface is composed of three layers: a tartan layer at the bottom, a wooden joist layer in the middle (in which the wooden joists are placed in a parallel and spaced manner) and a wooden parquet layer at the top. This construction gives the surface a compliant feature.

The data obtained in this study support the results of the previous ones which have found a negative relationship between surface compliance and oxygen consumption [1,2,9]. It has been proposed that a compliant elastic surface will passively store and return energy with each step, reducing the mechanical work performed by the runner's muscles [22]. In the same way, Kerdok *et al.* [26] have suggested that a reduction in metabolic cost occurs as the elastic rebound provided by a compliant surface replaces that otherwise provided by a runner's leg. The results of one study have suggested that inflexibility in certain areas of the musculoskeletal system may enhance running economy by increasing storage and return of elastic energy and minimizing the need for muscle-stabilizing activity [11].

On the other hand, Hardin *et al.* [24] have found a decrease in oxygen uptake as the leg stiffness increased, but, with increasing surface hardness. Therefore, they have suggested that metabolic cost is higher in more compliant surfaces. They have explained this inconsistency by differences in surface construction because their subjects mentioned a sensation of "running on sand" indicating that the surface may have had too much damping or inertia to effectively produce a "rebound" effect as in other surfaces used. Indeed, running on sand increases energy expenditure compared to running on hard surfaces [29,38,40], grass [37] and force platform [35] because sand doesn't return energy absorbed in the earlier phase of each step and, thus, this lost energy must be replaced by the muscles' activities at later phase of each step [10,29]. This is also true for jumping on the surfaces with very high shock absorption other than sand [16,33].

In locomotion the energy cost is thought to be determined by two factor together: the energy required for performing mechanical work and the energy required for generating muscular force [10,11]. By increasing leg stiffness on a compliant elastic surface, the human reduces the mechanical work done by the leg and increases the mechanical work done by the surface, and lowers the energy cost of generating muscular force. Because both the amount of work done by the person and the amount of force generated by the muscles would be reduced, the energetic cost of hopping or running is likely to be lower on a compliant elastic surface than on a hard surface [21].

Conclusion

In urban areas, one of the most important recreational activities is sport. If one participates in his sport longer, he will enjoys it more. This will help him to regain physical and spiritual energy that he lost during intense daily working. The duration of exercise is inversely related to muscle performance. In this study, muscle performance was found to be effected by the compliance of a sport surface. Parquet and EPDM were more compliant and less fatiguing surfaces, whereas asphalt and synthetic grass were hard and most fatiguing ones. Besides, natural grass, soil and tile powder were moderately compliant and fatiguing surfaces. The results of the present study suggest that it is better to use parquet and EPDM in building of indoor sport surfaces. Because parquet is not suitable for outdoor surfaces, they must be built with EPDM and natural grass. In addition, the usage of natural grass will have aesthetic and visual impacts and contribute to the amount of urban green area.

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