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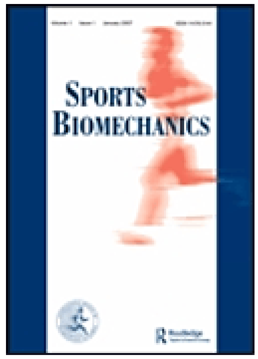

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Abstract

We aimed to clarify the effect of different futsal playing surface structural properties on the resultant change of direction (COD) performance, perceived traction, and frictional properties. Twenty experienced male university soccer players performed a COD slalom-course test and perceived traction evaluation on three different types of playing surfaces (area-elastic: AE, point-elastic no.1: PE1 and point-elastic no.2: PE2). Frictional properties of these surfaces were mechanically evaluated against a futsal shoe, using a hydraulic moving force platform, and expressed as available friction coefficient (AFC). In the COD performance test, the participants performed significantly better on the point-elastic surfaces (PE1 and PE2) when compared to the area-elastic surface (AE) ($p<0.05$). Also, the PE2 surface was found to have the highest perceived traction ($p<0.001$). The findings suggest that the relatively higher (4%) AFC explains the improvement in performance and traction perception on the PE2 surface. In this study, we successfully demonstrated that the structural difference (AE or PE) of futsal playing surface has a significant impact on the COD performance of experienced futsal players and their perceived level of traction (PE2) and the frictional properties.

Keywords: Soccer (MeSH), Athletic Performance (MeSH), Floors and Floorcoverings (MeSH), Friction (MeSH), Surface Properties (MeSH)

Introduction

Indoor soccer, commonly known as futsal, is one of the fastest-growing indoor sports in the world (Berdejo-del-Fresno, 2014; Moore & Radford, 2014). In 2019, the first official futsal test methods and standard requirements (FIFA, 2019) were released by the Fédération Internationale de Football Association (FIFA). The standard includes the requirement for futsal playing surface, which was adopted from that of multifunctional indoor sports floor (the EN 14904). However, as the FIFA standard does not specify a particular type of playing surface for futsal, four different surface systems are being used at this time, namely: point elastic, mixed elastic, area elastic, and combined elastic (Dixon et al., 2015) which can be made from various materials or material combinations. Therefore, it is very common for futsal players to compete on several types of surfaces, namely a wooden flooring [area-elastic (AE)] or on various types of synthetic surfaces [point-elastic surface (PE)]. Futsal is characterised as a high intensity sport with many fast-paced changes of direction (Ismail & Nunome, 2021; Moore & Radford, 2014; Wolanski et al., 2017). These futsal-specific modalities and styles of play are additional factors that should be considered in the design of playing fields, since the sports surface is a crucial factor for injury risk (Dragoo & Braun, 2010; Pasanen et al., 2008) and athletic performance (Serrano et al., 2020).

Player–surface interactions in futsal could potentially be explained by several technical specifications such as the grip performance (friction/traction), shock-absorption level, and vertical deformation. Here, the nature of higher shock absorbency typically coincides with a larger vertical deformation of the playing surface, which is commonly perceived as a better protection and comfort for the players (Dixon et al., 2015). However, it is still unknown whether these aspects have substantial impact on player performance. A survey among soccer players revealed that the athletes set their highest priorities on the performance outcome, rather than injury prevention, when questioned about shoe–surface interactions (Hennig & Sterzing, 2010). It was also reported that the players specifically picked comfort and traction performance as the most preferred aspects of soccer shoes. This observation highlights the importance of traction properties from the perspective of player–surface interaction in football.

The player–surface traction performance is typically quantified as the available friction coefficient (AFC) commonly measured using mechanical tests (Blanchette & Powers, 2015; Iraqi et al., 2018). Meanwhile, athletic performance regarding footwear–surface interactions are typically assessed by sport-specific motor performance, for example sprinting or sprinting including change of direction (COD) movements. These functional tests would provide important information as a direct parameter assessing the functionality of footwear–surface interactions (Sterzing et al. 2007), as well as a direct performance indicator of futsal playing ability (Sekulic et al., 2019). Moreover, athlete–floor interface has also been studied based on the player's perception of the traction performance (Gronqvist et al., 1993; Morio et al., 2015, 2017). A recent study reported a significant relationship between the measured friction coefficient and the perceived grip performance of athlete–sports surface interface (Morio et al., 2015). Therefore, both sports-specific functional tests and the perceived grip performance to a given sports surface, could potentially be used as a direct, strong indicator to illustrate the influence of playing surface on player's performance. Although it is widely accepted that the frictional properties of sports surface affect athletic performance (McGhie & Ettema, 2013; Worobets & Wannop, 2015) it still remains unclear whether there are any performance-related differences between area-elastic (AE) and point-elastic (PE) sports surfaces in futsal.

Therefore, the purpose of this study was to determine the effect of different types of futsal playing surfaces on: (1) change of direction performance of players, (2) players' perceived traction evaluation, and (3) mechanically measured available friction coefficients. It was hypothesized that substantial differences exist across all three parameters among different futsal playing surfaces.

Materials and Method

Study Design

We designed and conducted a mixed-methods study to determine the effect of floor choice on athletic performance in futsal. Our methodology included a randomized crossover study on completion time, and perceived level of traction ('poor' to 'excellent'), during a functional change of direction test, as well as a mechanical assessment of friction between futsal shoe and futsal surfaces.

Participants

In the crossover experiment of this study, twenty experienced male university soccer players (Kartal, 2016; Milanovic et al., 2011) were recruited (Age 20 ± 1.3 years old, body mass 66.6 ± 3.6 kg, height 174 ± 4 cm, soccer experience 13 ± 2 years; means +/- standard deviations). All participants had been involved at a competitive level for more than 10 years and were competing at university level at the time of inclusion. The exclusion criteria included any history of lower limb fracture and serious lower limb ligament injuries in the previous six months. All participants provided their written informed consent prior to the study in accordance with the research ethical approval obtained from the institutional research ethics committee.

Change of direction functional tests

The experimental set-up of the slalom-course; change of direction (COD) performance test is shown in Figure 1. The slalom course was adopted based on a previous study that investigated a similar soccer player–surface interaction in soccer (Sterzing et al., 2009). In addition, this study was also adopted based on past studies that compared futsal and soccer players, and found no significant differences in both sports on agility and change of direction performances (Kartal, 2016; Milanovic et al., 2011). Three identical test areas were prepared separately for three different EN 14904-certified futsal playing surfaces (AE: hardwood surface, PE1: vinyl surface 1, PE2: vinyl surface 2), which are commercially available and widely used. The technical specifications and material properties of these playing surfaces are shown in Table 1.

Shock-absorbency, vertical deformation, and sliding coefficient properties were obtained from the manufacturer's official technical data sheets. The hardness of each playing surface was measured using a Shore A and Shore D durometer (Shore A Durometer model: PCE-DX-A, and Shore D Durometer model: PCE-DD-D, PCE Instruments UK Ltd., Southampton Hampshire, United Kingdom). The mean surface hardness of Shore A and Shore D measurements was computed as the mean values of five repetitions on each playing surface. An infrared timing-gate system (Witty System, Microgate, Italy) with maximum precision (±0.4 milliseconds) was utilized to record the resultant completion time of the change of direction functional test. Throughout the functional test, all participants wore the same futsal shoes (Mizuno Monarcida Sala, model no. Q1GA1611) in their self-selected shoe size.

In the functional tests, each participant performed three maximal trials in a randomized order on each futsal playing surface (no two consecutive trials on the same surface). Prior to the actual trial, all participants were able to perform test-course familiarization on all three surfaces for as long as they needed. This was to ensure that each participant was well adapted to each different surface before actual trials were conducted (Morio & Sissler, 2016). The participants were then instructed to complete the functional change of direction course as fast as possible. The resultant completion time was measured by a pair of timing gate set at start/end point (Figure 1). Immediately after each run, all participants were also asked to evaluate their perceived shoe–playing surface traction performance using a 5-point Likert scale (1 = poor, 2 = fair, 3= average, 4 = good, 5 = excellent) (Bartholomew & Miller, 2002).

Available friction coefficient (AFC)

The available friction coefficient (AFC) for each playing surface was measured using a mechanical system consisting of a 4-degrees of freedom, hydraulic-powered robotic platform (van Doornik & Sinkjaer, 2007) equipped with a force plate sampling at 1200 Hz (Figure 2a). This specific setup has previously been demonstrated to precisely evaluate shoe–surface friction (Ismail et al., 2021; Jakobsen et al., 2022; Lysdal et al., 2022).

Above the moving platform, an artificial foot made from nylon was statically secured to a profile steel frame structure. During the mechanical test, the same model of futsal shoes that were used for the functional test were tightly secured to the artificial foot. Samples of playing surface were attached on the top of the force platform and secured by strong double-sided tape. To avoid any unwanted movements between the shoe and artificial foot, the anterior and posterior part of the of the shoe's upper was fixed to the artificial foot using bolts and nuts. The moving force platform was controlled using a customized system based on National Instruments technology (Mr. Kick, v. 2.030, Knud Larsen, Aalborg University, Denmark). The platform started at an initial position below the shoe and upon activation it moved towards the static shoe to apply the normal load to the shoe. Upon receiving the normal load, the force platform would move horizontally, creating a backward horizontal sliding motion between the top layer of the playing surface and the shoe outsole. The test conditions were set as: (1) Normal load = 500N, (2) Force platform sliding velocity at 0.3 m/s, (3) Shoe and playing surface sliding horizontally with contact angle at 0 degree (Figure 2a). The testing parameters were selected in accordance with EN ISO: 13287:2019. From this standard, the flat contact angle was selected due to the larger contact area between floor and outsole, and thus likely more representative of the high-demanding mid-stance during maximal effort change of directions in futsal. The test on each playing surface was repeated five times. Before and during the test, the shoe's outsole and the playing surfaces were prepared and cleaned in accordance with the ISO 13287:2019 test standard for dry assessments of slip resistance. The ground reaction forces (Fx, Fy, Fz) during the mechanical test were recorded using a force platform (AMTI-OPT464508HF-1000, Advanced Mechanical Technology, Inc. Watertown MA, USA) that was synchronized with Qualisys motion analysis system (Qualisys AB, Gothenburg, Sweden) and analysed using Visual3D v6 (C-Motion Inc., Maryland, USA). The friction coefficient was calculated using the following equation (1):

$$\text{Friction Coefficient, FC} = \frac{\sqrt{Fx^2 + Fy^2}}{|Fz|} \quad (1)$$

The AFC was defined as the mean value of friction coefficient during 100 ms of the steady-state condition of the friction coefficient curve (Figure 2b) (Morio et al., 2015).

Statistical analysis

The resultant time of the functional test and the score of perceived traction performance across all surfaces were analysed by one-way ANOVA repeated measures ($p < 0.05$). Post-hoc Bonferroni analysis was then performed if necessary, at significance level of $p < 0.05$. All statistical analyses in this study were conducted using an open source statistical package (PSPP software version 1.0.1).

Results

Slalom test performance

On average, the fastest performance time was recorded when the participants ran on PE2 surface, yielding a 0.12-second advantage compared to PE1 and a 0.56-second advantage to AE. The participants also showed smaller coefficient of variation (CV) for the performance time when running on PE2 (0.069) compared to PE1 and AE surfaces (0.074 and 0.095 respectively). As shown in Figure 3, several statistical differences were observed. The performance time on PE2 [9.50 ± 0.66 (s)] and PE1 [9.62 ± 0.71 (s)] surfaces were significantly faster ($p<0.001$ and $p=0.01$ respectively; effect size Cohen's $f = 0.469$) compared to AE surface [10.06 ± 0.96 (s)] while there was no significant difference for the performance time between PE1 and PE2 surfaces (Figure 3).

Perceived traction performance

There were apparent differences among the three playing surfaces for the perceived traction during the functional tests ($p<0.01$; effect size Cohen's $f = 0.913$). Significantly higher perceived traction scores were obtained when the participants run on PE2 (4.43 ± 0.7: post hoc $p<0.001$) and PE1 surfaces (4.13 ± 0.7: post hoc $p<0.001$) than AE surface (2.5 ± 1.3), while no significant difference was found between PE1 and PE2 surfaces (Figures 4a).

Available friction coefficient (AFC)

The available friction coefficient (AFC) values ranged from 1.34 to 1.40 as shown in (Figure 4b). PE2 surface provided 4% of higher AFC (1.40 ± 0.004) when compared of other two playing surfaces (PE2: 1.35 ± 0.01; AE: 1.34 ± 0.01).

Discussion and Implications

The purpose of this study was to identify the effect of different types of futsal playing surfaces on performance of change of direction run, perceived traction evaluation, and mechanically measured available friction coefficient (AFC). We hypothesized that substantial differences exist across all three parameters among different futsal playing surfaces, and our findings have supported this hypothesis. The participants showed significantly faster completion times of the COD performance test and rated the perceived traction of the PE surfaces to be significantly better, compared to the AE surface. These outcomes are explicable by the mechanically measured frictional property of PE2 surface. This surface possessed relatively higher AFC (4%) when compared to the other two surfaces (Figure 4b). This finding is in line with a previous study (Morio & Herbaut, 2018), where a relatively high frictional surface was found to significantly decrease several important spatio-temporal parameters of running such as stance duration, braking duration and push-off duration, thereby improving resultant performance. In the present study, we succeeded in demonstrating consistent relationships among resultant COD performance, perceived traction, and mechanically measured AFC within the given conditions mimicking actual futsal specific player mobility.

In addition, the coefficient of variation (CV) of the resultant completion time when the participants run on PE2 surface was found to be lower from the other two surfaces (Figure 3). This finding suggests that the participants tend to execute the COD performance test in a more consistent manner when running on the PE2 surface. Again, it can be suggested that relatively higher AFC value of PE2 surface may allow the participants achieving less variant (inter-individual) resultant completion time. In one previous study it has been suggested that to avoid and reduce slipping risk, participants will run cautiously on a surface with lower frictional characteristics. This is because under those circumstances, participants do not have the full confidence in getting enough traction and tend to run slower on a given test protocol (Hennig & Sterzing, 2010). Another previous study (Morio & Herbaut, 2018) also revealed that when performing a COD run on a low-traction surface, participants would alter the neuromechanical strategy to control their movement which could be associated with a reduced and inconsistent performance. Thus, it can be suggested that the present participants felt more confident when running on the PE2 surface due to relatively higher AFC and perceived traction.

Furthermore, the underlying foam layer of both synthetic floor surfaces (PE1 and PE2) enables a point elastic deformation of the surface which can increase the contact area and thereby increase the AFC (Moriyasu et al., 2019). This might explain why both synthetic surfaces outperform the AE hardwood surface on both perceived traction and completion time in the COD test. Besides, futsal shoes are normally manufactured without a midsole (foam) component. In the case of futsal, this highlights the importance floor deformation on perceived and available shoe–surface friction. The addition of a midsole in the shoe design would add a further cushioning layer, multiple times larger than that of PE1 and PE2, to the shoe–floor interaction that would decrease the importance of floor deformation. This also means, that the significant effects of floor type that we observed across all three outcome parameters would likely be diminished if our tests were to be conducted using cushioned indoor sports footwear. Generally, among the futsal players tested in this study, the artificial floors with higher traction was considered superior and their preferred choice of flooring for futsal matches. These floor types are, however, associated with an increased risk of injury compared to wooden flooring (Pasanen et al., 2008). This increased risk of injury is likely a result of the higher shoe–surface interaction (Thomson et al., 2015), where the point elastic deformation of the surface increases the contact area between outsole and floor (Moriyasu et al., 2019), and in some scenarios this might result in entrapment of the shoe into the surface.

Interestingly, a somewhat contradicting result has previously been reported for the differences between PE and AE surfaces during an agility test protocol (Serrano et al., 2020). Here, the participants performed change of direction significantly faster on the AE surface compared to the PE surface. However, despite their improved ability to change direction, no difference was found in overall completion time of the agility test between the surfaces (Serrano et al., 2020). Differences in test protocols, surface samples and participant age-groups, and sample size might partially explain the contradicting results. However, the fact that this study does not include information about frictional properties of the tested surfaces makes a direct comparison close to impossible. It is therefore unknown whether the AE surface used in that study might exhibit relatively higher AFC than that of the PE surface. The present findings suggest that frictional specification of playing surface could play a crucial role on player's COD performance and the mechanically measured frictional specification such as AFC to a specific shoe would help to estimate the actual grip nature during actual sporting situation.

In this study, all three playing surfaces possessed a similar frictional property (80–110 BPN in Table 1) from the product specification identified by the British Pendulum (Skid resistance test adopted by EN 14904 standard). In contrast, each surface performed differently when measured by mechanical test or evaluated by the participants, even though these two surfaces (PE1 and PE2) were made from a similar surface material. Perhaps, there were other differences in properties between PE1 and PE2 that could influence the overall surface charateristics such as surface roughness and hardness that was not disclosed by the manufacturer. As frictional properties of surfaces are specific to particular loading patterns (Clarke et al., 2012), the observed discrepancy can be explained by different loading patterns applied by these two tests. From the given findings, it should be highlighted that the mechanical test used in this study succeeded in discriminating concealed differences of frictional properties among the three surfaces. As the AFCs yielded in the current test corresponded with the outcome of COD performance and participant's evaluation, it can be suggested the loading pattern of the current test is closely mimicking actual player's to surface interaction during COD running.

The findings of present study are supported by Schrier et al. (2014), suggesting that available traction could be the performance limiting factor rather than surface compliance during a quick turn movement task. In this study, we also observed the surface with relatively lower hardness (PE2: Shore A 86.8 ± 0.8) showing a better traction performance among the tested surface materials (AE: Shore A >100; PE1: Shore A 90.6 ± 1.1). Mohan et al. (2015) investigated the influence of surface hardness on slip-resistance performance of visco-elastic materials with similar surface roughness but differences in hardness. Here, they revealed that softer materials tend to create greater effective contact area and more pronounced microscopic deformations in the mechanical interlocking between the shoe outsole and flooring surface asperities during shoe–surface interaction (Mohan en al., 2015). Similar findings were also reported by Derler et al. (2008) where softer shoe sole materials tend to generate relatively higher friction coefficients and increased slip-resistance performance. The current findings imply that the hardness of the surface may be warranted to be further investigated in order to more comprehensively understand the interaction of these factors in surface traction.

Finally, the sport-specific COD performance test used in this study did represent traction-related aspects between futsal footwear and playing surfaces, thereby supporting the findings of other previous studies with similar interest on playing surfaces (De Clercq et al., 2014; McGhie & Ettema, 2013). The order of the COD performance test results, were consistent with those of perceived traction evaluation and AFC. This supports the feasibility of functional performance tests with multiple CODs to evaluate effect of shoe–playing surface interactions.

This study is not without limitations. First, the study only focused on one type of hardwood flooring and two types of vinyl flooring. It should be acknowledged that there are many other types and manufacturers of area-elastic and point-elastic flooring materials that are commercially used for futsal. Therefore, the present findings should not be generalised for all types of area-elastic and point-elastic flooring materials. Second, the slalom-course functional test was effective to differentiate the level of functional performance between different type of flooring. However, it remains unknown whether a higher traction floor would have substantial influence on the outcome of a futsal match, since both teams would benefit from the same surface during a match. Thus, future works related to this topic should include testing of additional types of futsal flooring, both mechanically and with relevant functional tests of futsal-specific motions.

Conclusion

In this study, we demonstrated a significant influence of futsal playing surfaces on player change of direction performance, player's perceived traction, and mechanically determined available friction coefficient. The point-elastic surface (PE2) used in this study was found to be superior across all three measured outcome parameters compared to the other surfaces. From this, it can be concluded that the structure of playing surface and its available friction coefficient can influence the change of direction performance and perceived traction among futsal players. Critical values of shoe–surface friction coefficient were perceived differently by human participants and these differences have translated into a better performance of change of direction in futsal.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationship that could have appeared to influence the work reported in this study.

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Table 1. Technical specifications of playing surfaces

Figure 1. (a) Slalom-course change of direction functional test, and (b) Playing surfaces and shoes used in the study.

Figure 2. (a) Moving force platform for AFC measurement, and (b) example of a typical friction coefficient curve derived from the force platform measurement.

Figure 3. Distribution of resultant time of change of direction functional test. Red dotted lines show the group average († indicates a significant difference of Bonferroni post-hoc analysis ($p<0.01$); ‡ indicates a significant difference of Bonferroni post-hoc analysis ($p<0.001$)).

Figure 4. Average (±SD) of (a) perceived traction and (b) available friction coefficient (‡ indicates a significant difference of Bonferroni post-hoc analysis ($p<0.05$)).

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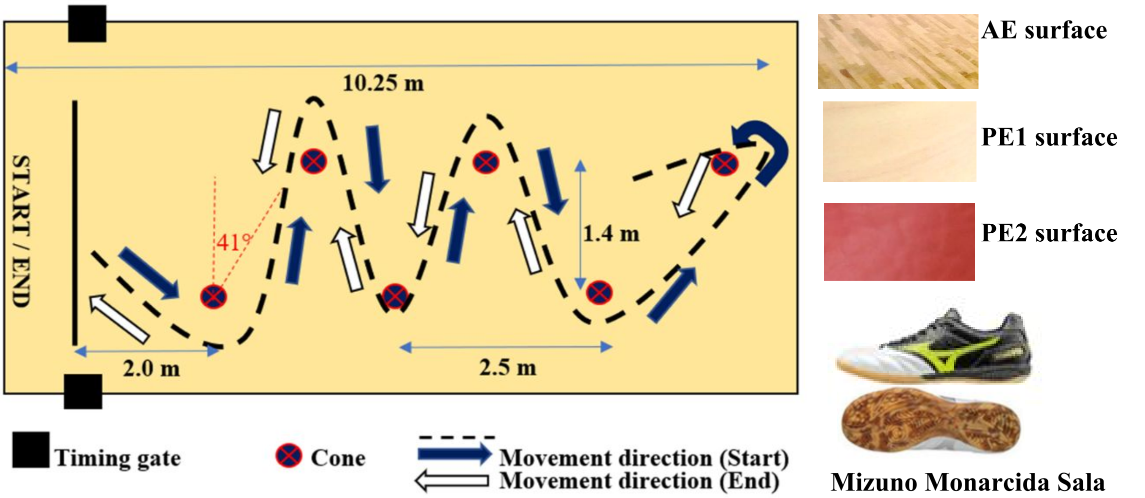
Table 1. Technical specifications of playing surfaces

Flooring surface/ model	Technical specifications				
	Shock-absorption	Vertical deformation	Sliding coefficient (British Pendulum Number, BPN)	Surface hardness (Shore A)	Surface hardness (Shore D)
Area-elastic (Hardwood): AE Junckers Beech Sylvasport	40 - 55%	1.8 – 3.5mm	80 - 110	>100	67.8 ± 0.6
Point-elastic 1 (Vinyl): PE1 Taraflex® Multi-Use 6.2	25 - 35%	<2.0mm	80 - 110	90.6 ± 1.1	47.7 ± 0.3
Point-elastic 2 (Vinyl): PE2 Taraflex® Sport M Evolution	25 - 35%	<2.0mm	80 - 110	86.8 ± 0.8	41.2 ± 1.3



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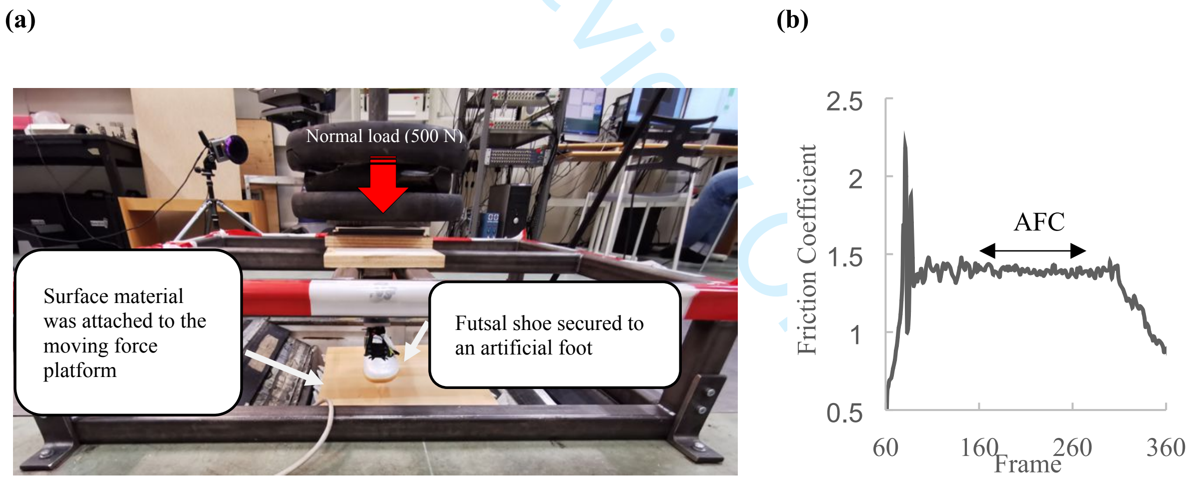

Figure 2. (a) Moving force platform for AFC measurement, and (b) example of a typical friction coefficient curve derived from the force platform measurement.

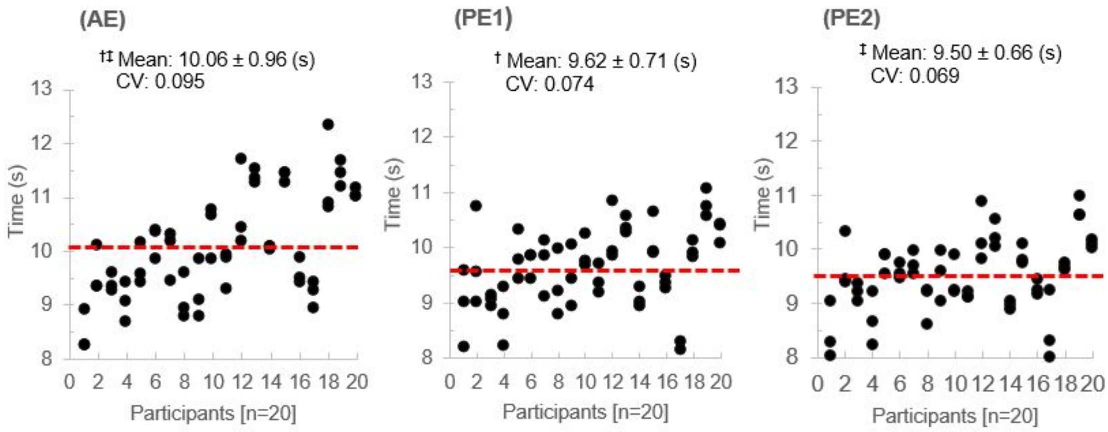

Figure 3. Distribution of resultant time of change of direction functional test. Red dotted lines show the group average († indicates a significant difference of Bonferroni post-hoc analysis ($p<0.01$); ‡ indicates a significant difference of Bonferroni post-hoc analysis ($p<0.001$)).

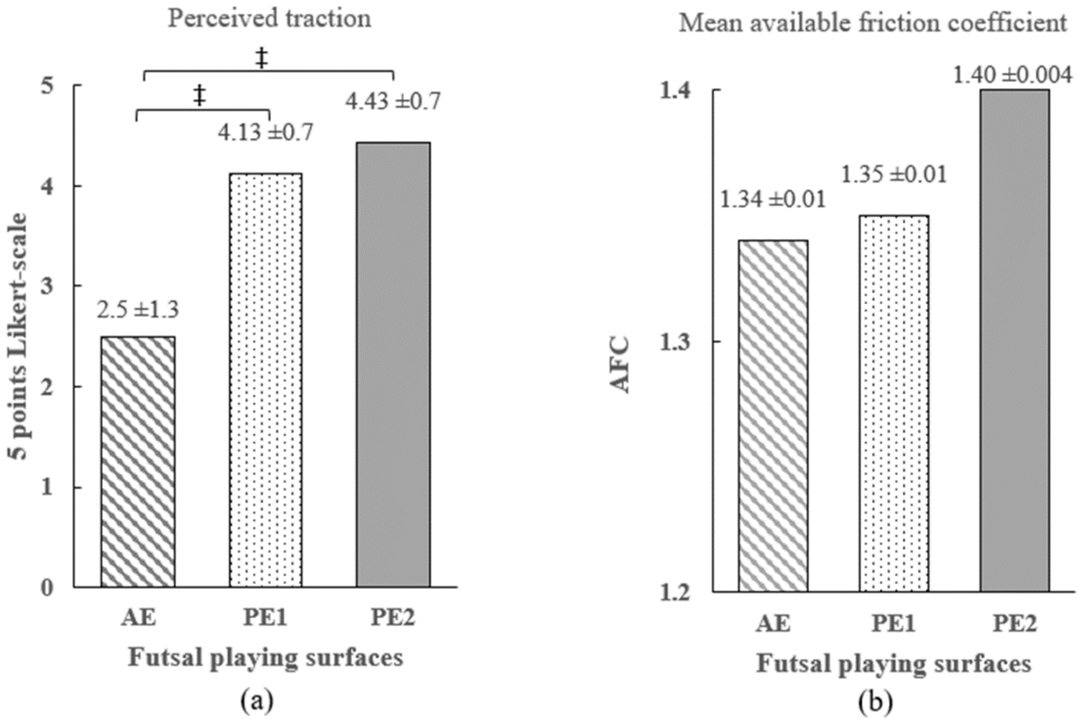

Figure 4. Average (±SD) of (a) perceived traction and (b) available friction coefficient (‡ indicates a significant difference of Bonferroni post-hoc analysis ($p<0.001$)).