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学位論文題目	FOOTWEAR AND PLAYING SURFACE INTERACTION IN FUTSAL （フットサルにおけるフットウェアとコートサーフェイスとの相互作用の解明）
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内　容　の　要　旨

【Introduction】

This PhD. thesis aimed to expand the understanding and knowledge on futsal footwear's outsoles and futsal playing surfaces interaction by providing novel quantitative data. This project consists of a series of studies and was initiated by analyzing the key performance indicators and the movement characteristics of elite futsal matches to determine important and relevant aspects of footwear and playing surface interaction. Based on these initial findings, the interactions between footwear and playing surfaces in futsal from the view point of mechanical properties, human dynamic performance outcomes and perceived tractions were investigated.

Study 1

The visual representation of futsal shoes outsole tread groove design and its mechanical traction, dynamic human traction performance, and perceived traction during change of direction and straight sprint tasks

【Method】

Thirty-nine university level athletes participated two human performance tests (multiple v-cut and 5m/20m straight sprint) on a hardwood flooring facility using three pairs of futsal shoes that were systematically ranked based on apparent design simplicity/complexity (1 = simple, 2 = moderate, and 3 = complex). All participants were asked to evaluate their perceived shoe-playing surface overall traction after each trial using 5-points Likert scale (1 = poor, 2 = fair, 3= average, 4 = good, 5 = excellent). Further mechanical testing was carried out to measure each shoe's actual available traction coefficient on a dry hardwood surface (AFC).

【Results】

Among the three shoes, there were significant differences of AFCs (rank 2 > rank 3 > rank 1: $p<0.001$). The shoes with higher AFC (1.34: rank 2 and 1.30: rank 3) had significant impact on the multiple v-cut performance ($p<0.05$) and on perceived traction ($p<0.05$) when compared to the shoe with lower AFC (1.25: rank 1). No significant differences were observed across all shoe ranks for the initial (5m) and resultant (20m) sprint times for the straight sprint test.

【Discussion】

These findings indicated that the simplex outsole performed worst and the moderately complex outsole performed best for mechanical traction, human performance, and perceived traction. Moreover, compared with the moderately complex outsole, the most complex outsole comes with several specific features did not induce any advantage of traction performance.

【Conclusion】

The AFCs of three tested shoes most likely explain the differences in dynamic human traction performance and perceived traction during the test including multiple change of direction.

Study 2

Effect of different futsal playing surface characteristics on change of direction performance, participant's perceived traction and available friction coefficient

【Method】

Twenty experienced male university soccer players performed a slalom-course change of direction (COD) performance test on three different futsal playing surfaces (area-elastic: AE, point-elastic no.1: PE1 and point-elastic no.2: PE2). All surfaces possessed different surface hardness property. Throughout the dynamic test, all participants wore the same futsal shoes (Rank 2/ S2) although differing in size. All participants were asked to evaluate their perceived shoe-playing surface overall traction after each trial using 5-points Likert scale (1 = poor, 2 = fair, 3= average, 4 = good, 5 = excellent). Available friction coefficient (AFC) for each playing surface was mechanically measured using a hydraulic-powered moving force platform.

【Results】
The participants performed significantly better on PE2 [9.50 ± 0.66 (s)] and PE1 [9.62 ± 0.71 (s)] surfaces compared to AE surface [10.06 ± 0.96 (s)] ($p<0.001$ and $p=0.01$ respectively). No significant difference was found between PE1 and PE2 surfaces. The participants evaluated significantly higher perceived traction performance when running 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, while no significant difference was found between PE1 and PE2 surfaces. The shoe-surface AFC values ranged from 1.34 to 1.40. PE2 surface possessed significantly higher AFC (1.40 ± 0.004) when compared of other two playing surfaces (PE2: 1.35 ± 0.01; AE: 1.34 ± 0.01).

【Discussion】
It was suggested that significantly higher AFC of PE2 surface compared to the other two surfaces ($p<0.001$) may contribute to the observed findings. The current findings implied that the hardness of surface property may be warranted to investigate in order to explain some background of actual surface traction performance.

【Conclusion】
The futsal playing surface properties have significant impact on COD performance, perceived traction and AFC.

Study 3
Mechanical testing of futsal footwear and playing surface: A perspective from the mechanically measured friction coefficient and traction force under different footwear and playing surface combinations

【Method】
Three pairs of futsal footwear (similar to those reported in Study 1) and three

different futsal playing surfaces (similar to those reported in Study 2) were selected for the mechanical tests. Traction force (TF) and available friction coefficient (AFC) for each footwear and playing surface combination was mechanically measured using a hydraulic-powered moving force platform. AFC and TF measurements were carried out with nine footwear-playing surface combinations (3×3) under dry friction condition. The test condition was set as the followings: 1) the offset normal load = 500N, 2) the sliding velocity of the force platform was 0.3 m/s and 3) the force platform slides against footwear outsole in two directions (anteroposterior: APAFC/APTF and mediolateral: MLAFC/MLTF) with contact angle at 0 degree.

【Results】

Results have indicated significant effects of footwear, playing surface and footwear-surface interaction on both the APAFCs and MLAFCs ($p<0.001$ of all statistical analysis). For traction force (TF), for all footwear-surface combinations, the combination with PE2 surface and S2 shoe have produced significantly higher traction forces when compared to other playing surfaces and footwear combinations in both sliding orientations.

【Discussion】

Of nine footwear and playing surface combinations, combinations includes either S2 shoe or PE2 surface tended to produce higher AFC values. As AFC = TF/normal load and the normal load is constant (500 N) in the current test set, the magnitude of TF is exclusive determinant of AFC values. This finding was nicely matched with previous findings (Study 2) regarding dynamic human traction and perceived traction, in which S2 shoe-PE2 surface combination was found to promote a better performance than other footwear-surface combinations.

【Conclusion】

Footwear-playing surface with different combinations produce different available friction coefficients and traction forces that could potentially influence actual athlete traction performance.

【Overall Conclusions】

Overall, the commercially available shoes and playing surfaces tested in this study produced AFC values ranged between 1.00-1.40 in dry friction condition. This considerably wider range of AFC indicates that the differences in outsole tread groove design of a shoe and playing surface properties have substantial effect on the shoe-playing surface interaction. There were a well-matched pair of a shoe and a playing surface producing significantly higher AFCs compared to other shoe and playing surface combinations. In addition, it was also identified that the tested shoes provide a substantially different AFC for mediolateral direction of the shoe than that of anteroposterior direction. This finding highlighted the importance of mediolateral AFC, which had never been gathered attention from footwear researchers.

審査の結果の要旨

1.研究の概要
This research project aimed to expand the understanding and knowledge on futsal footwear' s outsoles and futsal playing surface interaction by providing novel quantitative data. This project consists of a series of studies and was initiated by analyzing the key performance indicators and the movement characteristics of elite futsal matches to determine important and relevant aspects of footwear and playing surface interaction. Based on these initial findings, we designed further studies focused on the interactions between footwear and playing surface in futsal relevant conditions from the view point of mechanical properties, human dynamic performance outcomes and perceived tractions. A novel mechanical approach using a moving force platform was followed and used to test various types of footwear and playing surface interaction under different conditions. A series of these studies provided new, significant insights on the influence of footwear and playing surface on traction performance.

2.テーマの斬新性
One of the novelties of this project was to use the approach of notation analysis to identify and extract key movement characteristics in futsal. This linkage between futsal movement characteristics and resultant match performance provided the underpinning on why several futsal specific movements are used for further human and mechanical tests. Based on these initial findings, footwear and playing surface interaction in futsal has been investigated. A series of studies consisted of dynamic human traction test, perceived traction evaluation and mechanical traction performance of futsal shoes were followed to form comprehensive research on futsal footwear and surface. Another outstanding

novelty of this project was to combine human traction test and mechanical traction test to evaluate shoe-surface interaction in futsal. The dynamic human traction test was designed to include high-traction demanded translational movement from our initial findings. For the outsole of futsal shoes, a long straight groove-line along the horizontal and lateral directions were found to produce significantly higher available friction coefficient (mechanically measured), significantly faster change of direction run (human test) and higher perceived traction (human test) compared to other outsoles features due to ‘the trench effect’ phenomenon while this outsole tread feature has no substantial effect on straight sprint performance (human test). In contrast to the literature, footwear with the lowest forefoot bending stiffness did not suffer any detriments on resultant performance (human test). Moreover, players performed significantly faster and perceived higher traction on the surface possess higher available friction coefficient compared to the others with lower available friction coefficients. Finally, it is confirmed that there is a good footwear-playing surface combination produces relatively higher available friction coefficient, higher traction force, better dynamic human performance and higher perceived traction.

3.研究の有用性

The current findings of this research provided answers to gain our understanding for the following research questions regarding the nature of game and footwear-surface interaction in futsal.

1.What are the key performance indicators which can discriminate the resultant outcome of a single futsal match and of a whole of tournament based on selected match statistics in elite futsal matches?
2.How do different tournament stages influence futsal player’s movement profiles?
3.Is there a way of categorizing futsal shoe outsole designs from their visual representations?
4.How do different futsal shoe tread groove design effect the mechanical testing and dynamic traction performance?
5.Does futsal shoe bending stiffness have substantial influence on dynamic traction performance?
6.Do different types of futsal playing surfaces influence the sprint, change of direction performance, perceived traction performance, and available friction

coefficient?
7.Do different outsole tread grove designs and different playing surfaces interaction tested under various test conditions have substantial influence on the mechanical test outcomes?

4.外部評価
The following five papers published in peer reviewed journals form the core part of the thesis for Doctor of Philosophy (Ph D). This fact firmly guaranteed its scientific validity, which is evaluated externally.

1.Ismail, S. I., & Nunome, H., & Tamura., Y. (2020). Does visual representation of futsal shoes outsole tread groove design resemblance its mechanical traction, dynamic human traction performance, and perceived traction during change of direction and straight sprint tasks? Footwear Science (Published online on October 12th, 2020). https://doi.org/10.1080/19424280.2020.1825534
2.Ismail, S. I., & Nunome, H. (in-press). The effect of different tournament stages on the movement dynamics of futsal players while in ball-possession. Human Movement, 22(4), (Accepted for publication on May 16th, 2020).
3.Ismail, S. I., & Nunome, H. (2020). The key performance indicators that discriminate winning and losing, and successful and unsuccessful teams during 2016 FIFA Futsal World Cup. Science and Medicine in Football, 4(1), 68-75. https://doi.org/10.1080/24733938.2019.1662937
4.Ismail, S. I., Nunome, H., Tamura, Y., Iga, T., & Sugi, S. (2020). Sprint and Change of Direction Performances on Three Different Futsal Playing Surfaces. Proceedings, 49(1) 1-5. https://doi.org/10.3390/proceedings2020049017
5.Ismail, S. I., Nunome, H., Marzuki, F. F., & Su'aidi, I. (2018). The Influence of Additional Surface on Force Platform's Ground Reaction Force Data During Walking and Running. American Journal of Sports Science, 6(3), 78-82. https://doi: 10.11648/j.ajss.20180603.12

5.主な質疑応答
Question 1: What is the difference between friction and traction?
Answer: In principle, both are similar. Friction and traction are the properties which enable the player to make movements necessary in sport without excessive slipping or falling. In classical mechanics, friction is defined as the force resisting the relative motion of solid surfaces, fluid layers, and material. In shoe-surface context, traction is defined as the frictional

coefficient between different shoes and surfaces. Hence, friction represent the resistive force between two surface in-contact, while traction represent the force that attempts to gain motion by contacting the other body. Therefore, from the practical and application perspective, friction and traction is not the same.

Question 2: Why slalom course (zig-zag run course) test and 505-agility test were chosen for the human dynamic test in this study?
Answer: As been presented from the in-game scenario study in this PhD thesis, side-cut run and u-cut run were two types of movements performed by futsal players that can influence the game outcome. The side-cut and u-cut performance were intended to be individually analysed and therefore two separate independent tests were selected. Therefore, the slalom course was selected to specifically represent side-cut run due to its narrow COD angle, while 505-agility test was selected for its 180-degree COD aspect.

Question 3: In this study, do all three shoes selected for analysis possessed similar outsole material?
Answer: Yes, all three shoes have similar rubber outsole material and all possessed similar material hardness properties as well.

Question 4: Will there be any difference in terms of the traction property if the slalom course were conducted in two different approach: 1) normally running around the cone, and 2) side-cut run from one cone to another?
Answer: Yes. In normal running, the traction demand for the footwear-playing surface interaction would be lower as compared to the side-cut run. This is because in side-cut run, higher traction would be required more in mediolateral direction when players planted their foot to the surface and then immediately changing direction using the opposite leg to move sideways quickly. This mediolaterally-high traction demand is not required if the players normally run around the cone.

6.審査委員会の結論

After careful considerations of the evaluations by all the judges, the panel of judges reached the following conclusion. Judging from the above-mentioned descriptions regarding this thesis and its final defense (oral) made by the candidate, the thesis from the candidate includes outstanding novelty in terms of Sports Biomechanics and the candidate himself deserves to gain Doctor of Philosophy in Sports Sciences.