Lecture Notes in Bioengineering

Syed Faris Syed Omar ·
Mohd Hasnun Arif Hassan ·
Alexander Casson · Alan Godfrey ·
Anwar P. P. Abdul Majeed *Editors*

Innovation and Technology in Sports

Proceedings of the International Conference on Innovation and Technology in Sports, (ICITS) 2022, Malaysia

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Preface

The International Conference on Innovation and Technology in Sports (ICITS 2022) is the first edition of the conference organised by the Malaysian Sports Technology Association (MySTA) and the National Sports Institute, Malaysia, which is supported by the Malaysian Board of Technology (MBOT). This conference is one of the platforms to bring together those involved in the sports industry including researchers, engineers and technologists to share the latest research and innovation in the field of sports technology to further empower the sports industry. This volume hosts 24 papers that have been thoroughly reviewed by the appointed technical review committee that consists of various experts in the field of sports.

A sincere thanks to all members of the organising committee for making the conference a success. Not forgetting our sponsors, Reveal DNA from Genomas as the main sponsor of this conference and other sponsors consisting of Futurise, The Institution of Engineering (IET) Malaysia Local Network, Gatorade, Bleu, Goodday, Yakult, ATF Sport and also Richard Wee Chambers for their kind gesture and continuous support. We also would like to extend our appreciation to the authors for contributing valuable papers to the proceedings. We hope this book will intensify the knowledge sharing amongst colleagues in the field of sports technology and innovation.

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Contents

Kinematic of Body Segments, the Force Growth, and the Speed of the Rowing

Ab Aziz Mohd Yusof, Hazim Sharudin, Wan Muhammad Syahmi Wan Fauzi, and Muhamad Noor Harun

Abstract The rowing performance depends on how fast the boat moves during the race, contributed by the generated forces and rower kinematic. Based on that interest, the objective of the study is to investigate the kinematics during a stroke by including the generated forces and related speed. The study was carried out using a dynamic rowing simulator which simplified the rowing boat and mimicked the rowing biomechanics and the hydrodynamic condition. The experimental result found that extending the legs generated a higher force to boost the speed. Using legs, trunk and arms in their overlapping motion helps the rower instantly reach the peak effort and maintain the pressure. About 496–539 N of the handle forces were captured by the simulator, which generated a blade force peak between 222 and 234 N, with the average peak force achieved for these three strokes being 46% of the drive. The oar angular speed captured was from 1 to 1.5 rad/s. In return, accelerate the boat at two m/s for 25–27 stroke/min rowing stroke. In conclusion, the combination of the kinematic, force and speed related to the rowing during the stroke is important to consider during the study. The effect of rower kinematic can be observed directly in the forces generated and associated speeds.

Keywords Rowing · Kinematic · Force · Speed

1 Introduction

The rowing race involves propelling the boat using an oar to generate the hydrodynamic force on the fully submerged blade. The race intends to move forward faster by maximising the generated force, which pushes the boat to a higher speed. During the beginning, the rower rows with precision strokes and produces high horsepower

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to develop force and speeds as quickly as possible. The performance highly depends on the rower's kinematic, the generated force and speed during the stroke. These three aspects are important to consider since they will help the rower move forward and be comfortable manipulating the rest of the race.

During the stroke, rowers transfer the generated energy to biomechanics capability through body kinematics using three body segments, arms, trunk and legs. The rower moves the body and generates force as the handle force. The force rapidly grew to achieve a peak at an average of 40% of the drive event. Biomechanics can be improved through anthropometry, body weight, stroke rate, and rowing style [1, 2]. V. Kleshnev reported that the average amount of power applied during the stroke was 46.4 ± 4.5% from the legs, 30.9 ± 5.2% from the trunk, and 22.7 ± 5.2% from the arms [3]. Changing the percentage of power from any of these body segments consequently changes the handle force pattern known as stroke style [4].

The rowing stroke contains four phrases repeated in the same sequence over the race event. The phases are begun with a catch, followed by the drive, finish, and end with recovery before it is repeated [3, 5–7]. The drive phase is the main contributor to hydrodynamic propulsion force, and the other phases are only complementary to the stroke [8]. During the catch phase, the blade is initially submerged, and then it is followed by the drive phase, where the blade travels through the arc path. The finish phase is achieved when the blade reaches the maximum travelling arc and is prepared to be lifted. The final phase is recovery, where the blade feathers and travels in the air, then return to the catch position. The blade force is developed based on the blade-boat relative speed. In this aspect, the oar blade moves faster than the boat, and the relative speed is obtained by minus the oar blade speed with boat speed. If the oar blade is faster than the boat, negative pressure is generated on the front of the blade to propel the boat. But if the oar blade is slower than the boat, negative pressure is generated at the back of the blade, consequently slowing the boat down.

This study was carried out to investigate how rower kinematics relates to force and speed growth. The study focused on the start phase, where force and speed gradually develop as the rower tries to move the boat from the stationary condition before extending up to 3 strokes before force and speed fully develop. As far as authors consent, very limited literature investigates kinematic, force and speed in one study to elucidate the dependency between them.

2 Method

2.1 Experimental Approach

The study mimics the rowing biomechanics and the hydrodynamic condition using a dynamic rowing simulator shown in Fig. 1. This approach eliminated the skin drag on the rowing shell, heave and pitch motion, balancing effect experienced by the rower, and bow surges the boat move. Furthermore, as the boat was fully controlled, the blade's hydrodynamic force was efficiently utilised to propel the boat.

The dynamic rowing simulator used in the experiment consisted of three main parts: (1) the simplified boat. (2) boat rail. (3) water tank. The simplified boat moved freely along the rail during the experiment using roller bearings. An oar with a Macon blade was attached to the boat through the oar lock placed at the right wall.

The size of the simplified boat was 1.50 × 0.69 × 0.36 m for length, width and height, respectively. The simplified rowing boat and oar weight was 35 kg and 2.5 kg. The rail size was 15.00 × 0.95 × 0.90 m, designed to fit the simplified rowing boat. The water tank size was 15.00 × 5.00 × 0.90 m for length, width and height.

Handle and blade hydrodynamic forces were sensed according to the shaft strain bending [9]. Four foil strain gauges FLA-6–350-17 manufactured by Tokyo Sokki Kenkyujo were used in the experiment. Strain gauges were glued on the shaft using a general-purpose Cyanoacrylate adhesive material. Two strain gauges were located on the outboard shaft, one on the tension and the other on the compression side, 24 cm away from the oar collar. The other two strain gauges were placed inboard at the region experiencing tension and compression. Both inboard strain gauges were located 15 cm from the oar collar.

The oar rotational angle and boat velocity were monitored using the rotary encoder DFS60A-S4PC65536, manufactured by SICK and attached to a simplified rowing boat. The one encoder was on top of the gate, and the second one was on the roller.

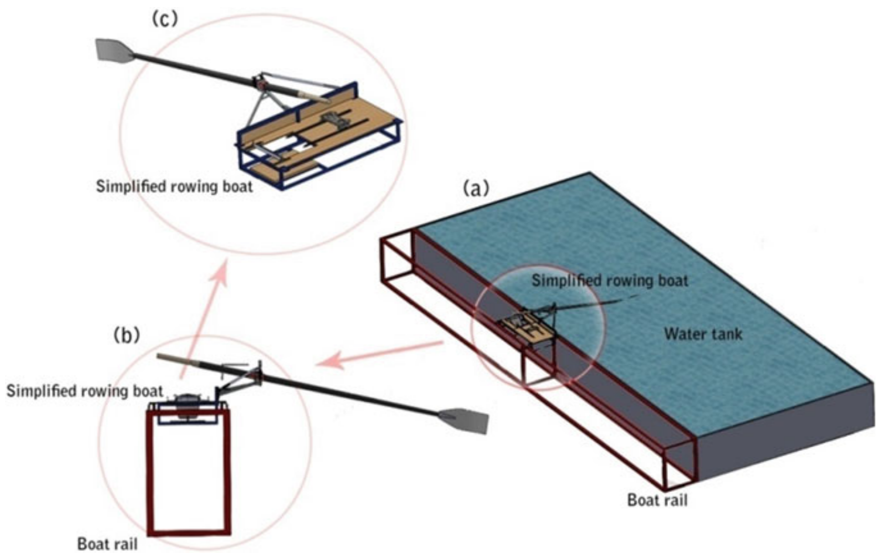

Fig. 1 Experimental equipment used in the study; **a** complete setup of rowing equipment which consisted of the simplified boat, rail, and water tank, **b** model of the rail and how the simplified boat was placed and **c** model of the simplified boat that replicated the real model of the rowing boat

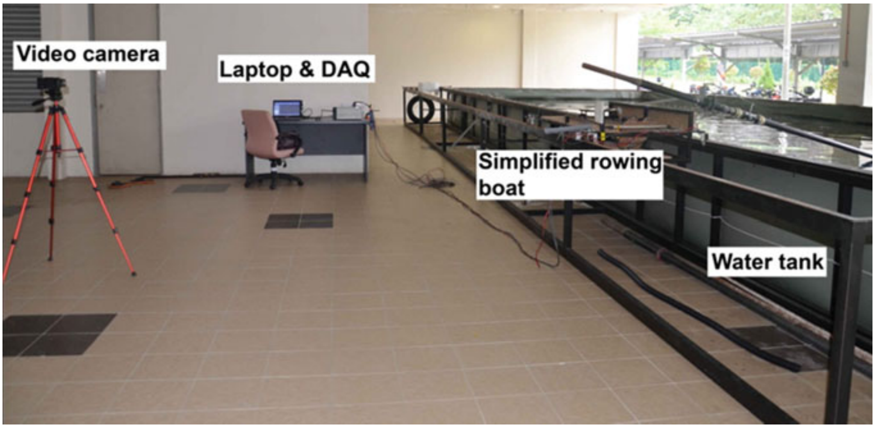

Fig. 2 Experimental setup for the study

Strain gauges and encoders were connected to a National Instrument data acquisition system with NI 9219 and NI 9401 modules and slotted into the NI9174 chassis.

The experiments began by pulling the oar handle towards the rower. Next, the motion of the rower body segments was captured using a camera (Sony FDR-AXP35) at 25 frames per second, as shown in Fig. 2. The experimental procedure was used to simultaneously capture rower kinematic, handle force, and blade hydrodynamics.

3 Result

3.1 Rower Kinematics During the Drive Phase

Figure 3a shows how the rower situated his body in the hatched position at the start. Figure 3b shows the body segment kinematic during the drive. The results were obtained from video analysis.

The stroke is started by compressing the legs, tilting the trunk forward and straightening the arms to achieve the maximum catch angle to initiate the stroke. The legs then extended backwards for the first 0.4 s, while the trunk and arms were maintained at the same pose as the initial. An increasing leg extension from 0.4 to 0.6 s caused the sliding seat to move for 12 cm. After 0.6 s, a significant leg trunk happens to cause the sliding seat to move to the maximum distance of 23 cm. The stoke then continues by bending the arms and increasing the oar angular speed. The leg extension stop at 0.8 s. Instead, the oar handle moved due to the increasing trunk tile angle, where the angle changed about 68° relative to the original position. Besides that, after half of the drive, the arms also moved quicker by moving the handle faster towards the body, which made the total elbow bending equally to 83°. By the end of the drive,

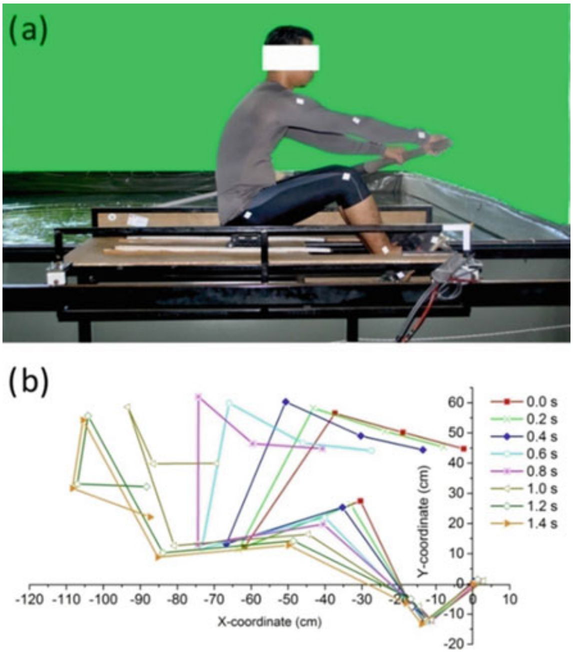

Fig. 3 **a** Rower equipped with the marker for video analysis **b** Kinematic of rower for the first stroke

these three body segments coordinated to achieve the finish, which can be seen at 1.0 and 1.2 s. At the end of the drive at 1.4 s, only the rower's arm removed the blade from the water, whereas other body segments stopped as they reached the maximum reachable distance.

3.2 Force Profile of the Drive Phase

The handle and the corresponding blade hydrodynamic force were recorded using strain gauges, shown in Fig. 4. The force increased gradually during the early drive phase due to rower kinematic. As the force magnitude reached 46% of the drive, it decreased gradually to zero as the blade was lifted from the water. The maximum handle forces applied by the rower at the starting phase are 496 N, where 539 N for the second stroke and 501 N for the third stroke.

The blade force is the hydrodynamic force that acts on the blade due to the relative velocity between the oar rotation and boat translation. As soon as the stroke started, the blade hydrodynamic force increased gradually to the highest peak of 222 N at 46% of the first drive. Meanwhile, for the second stroke, a peak force of 227 N was achieved at 42% of the second drive. The last peak of 234 N was reached at 50% of the drive. The average peak force achieved for these three strokes is 46% of the

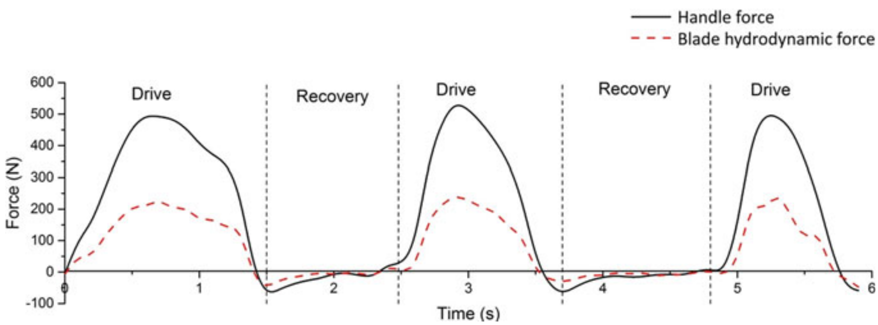

Fig. 4 Handle and blade hydrodynamic force act on the oar

drive. The smoothness of the blade graph was lower than the handling graph due to the violence of the water surface as the blade travelled in water.

The boat increased with the increment of the blade force at power was applied to propel the boat. However, once the magnitude of handle force passes 50% of the total drive phase, force reduction then happens. But the boat continues to gain speed until it reaches the end of the drive phase. The increasing boat speed influences the situation due to the cruise inertia. Meanwhile, the reduction in the relative speed between the blade and the boat speed affected the blade force [10]. As the blade force reduced, the oar was rotated easily, which is represented by a higher angular speed at the end of the drive but contains less power.

3.3 Speed Profile of the Oar and Boat

The best three speeds and oar angular speeds were captured as in Fig. 5. The oar angular speed grows gradually up to 1 rad/s for 80% of drive time. Once the oar reaches the finishing phase, the blade overturns, illustrated as negative notation. For most overturn or recovery phases, the average travelling velocity is at 1.5 rad/s, 33% faster than drive. Similar to the first stroke, the oar angular speed of the second stroke increased gradually from zero to the maximum angular speed. The number was 1.4 rad/s higher and 0.3 s shorter in duration than the first stroke. Meanwhile, the third stroke was 0.1 s faster than the second and maintained the peak angular speed.

Since the rowing boat was initially stationary, most of the force applied was used to overcome the stationary inertia. As a result, the boat moved slower before accelerating to achieve two m/s, as shown in Fig. 5. However, during the translation stage between the first and second stroke, speed reduction happened as the rower returned to the hatch position to start the second stroke as the rower moved in the opposite direction of the boat. Since the boat had already moved and the oar was rotated faster than the initial stroke, the boat seemed to move even faster related

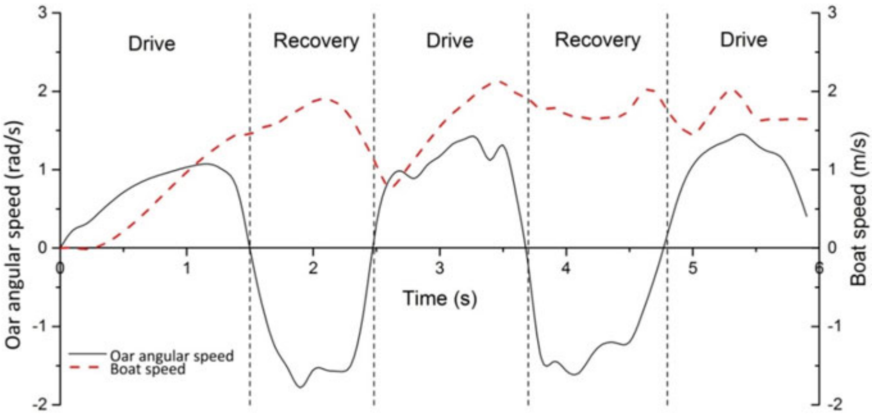

Fig. 5 Angular speed of the oar during the start and rowing boat velocity profile

to the increment of the stroke rate from 25 strokes/min at the initial stroke to 26 strokes/min for the second stroke and 27 strokes/min for the third stroke.

4 Discussion

Leg, trunk and arm body segments were used during the stroke. Most of the power is contributed by the leg and trunk. The stroke began when the rower extended the legs and generated a large and boost force. The use of the leg is important as it contributes 46.4 ± 4.5% of the stroke power, as reported by Kleshnev [3]. The stroke was sustained with simultaneous emphasis on the leg extension, trunk alternation and the arms bending to extend the sweeping angle. The use of the trunk provided 30.9 ± 5.2% of the stroke power, and the arm provided 22.7 ± 5.2% of the stroke power [3]. There are several advantages of joining the use of legs, trunk and arms in their overlapping motion. The rower can reach the peak effort instantly and maintain the pressure on the blade to provide the propulsive force in accelerating the boat.

The average maximum handle force is 512 N with a standard deviation of 23 N, and the average corresponding blade force is 231 N with a standard deviation of 13 N. The handle and blade forces show a pattern as in Fig. 4. This study confirms that the oar is working according to the first-class lever. It shows the load, fulcrum and effort lever element arrangement, representing the handle force, oarlock and blade force. This concept agrees with Kleshnev study [6]. The ratio of the outboard to the inboard length of the oar is defined as the mechanical advantage. In this experimental study, the oar's mechanical advantage was 0.45. However, the value was small, less than one. However, the advantage of the first-class lever of the oar produced a larger arc sweeping distance and moved the boat forward within a short time with a small force on the blade as an anchor.

During the stroke, the oar is rotated faster, causing the oar to experience the inertia force. The effect of oar inertia force is seen during the catch and finish due to the rapid changing of the oar sweep direction. Figure 4 shows the force peak at the early stroke and the higher opposing force at the end of the drive. According to Kleshnev [11], during the catch, the inertia force effect helps the rower improve the body position by stretching the arm and shoulder muscle as the blade tends to rotate further forward. Before recovery, it is suggested to maximise the inertia force to improve the propulsion through a good finish technique. The blade rotation introduced a momentum-changing at the boat side, which caused speed disturbance during catch and finishing, as shown in Fig. 5. In addition, the oar inertia force caused additional moving mass acting on the boat, which made the boat roll along the longitudinal boat axis.

The fluctuation of boat speed during the stroke decreased the boat speed in motion disturbance. According to this study, three factors that influence the fluctuation of the boat were identified: first, fluid drag acting on the blade once the blade submerged during the catch. Once the blade is submerged for the catch, the blade's rotational speed is zero. This has caused drag resistance at the back of the blade, which resists the boat's motion. Second, changing the stroke phase from water support during the drive phase to unsupported water condition during the recovery phase. Between these phases, the energy to accelerate the boat is cut as the blade is lifted from the water. Third, the rower moved in the opposite direction compared to the boat velocity while returning to the catch position. It created additional momentum, which disturbed the boat's momentum. The fluctuation of boat speed can be reduced by increasing the stroke rate, especially during returning from the finish to the next catch position, because it reduces the time interval and maintains the power supply to the boat. During returning to the hatch body position, a smooth and soft movement should be envisaged by the rower to reduce the momentum of altering to avoid any disturbance of the boat velocity.

5 Conclusion

In conclusion, the handle force and blade hydrodynamic force were important in the kinematic or stroke style investigation to obtain the accurate boat speed for the performance evaluation. The right catch timing the controlled by the kinematic, which can be achieved by moving the blade at a suitable speed matching the boat speed. The performance can be increased by applying the right kinematic in the form of stroke style. Response of the kinematic happed directly in the form of force and speed. The fluctuation of the moving boat affects rowing efficiency. The right timing of blade placement can improve during the drive, better-finished phase and proper movement during returning to the catch position.

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Mechanical Testing of Futsal Footwear: Friction Coefficient Under Different Sliding Direction

Shariman Ismadi Ismail, Hiroyuki Nunome, Filip Gertz Lysdal, Uwe Gustav Kersting, Ahmad Faizal Salleh, and Hosni Hasan

Abstract This study aimed to clarify the differences on friction coefficient of footwear used in futsal when mechanically measured in two different sliding direction. Available Friction Coefficient (AFC) and Traction Force (TF) of three futsal footwear with different outsole design (S1, S2 and S3) were measured using a novel six-degree of freedom mechanical test in anteroposterior (AP) and mediolateral (ML) sliding direction. Results have shown differences of AFC value when measured in different sliding direction (AP and ML) for all three shoes. In addition, it was observed that S2 shoe was the least affected in terms of reduction of AFC value when compared between AP and ML direction. It was also observed that among the three shoes tested, S2 has produced the highest TF in both AP and ML direction as compared with other shoes. From these findings, it can be suggested that traction performance of sports footwear should be evaluated by multi-directional sliding approach, and conventional one directional footwear evaluation standard such as BE EN ISO 13287 is most likely not adequate to analyse sports footwear–sports playing surface traction performance in real world.

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Keywords Friction coefficient · Football codes · Shoes · Mechanical · Futsal · Force platform · Traction · Interaction

1 Introduction

There are several studies investigated the influence of outsole tread grooves on the friction coefficient [1–4]. Those researchers commonly used mechanical testers which examined the friction of footwear in a quasi-static condition in one (anteroposterior) sliding direction such as BE EN ISO 13287 (2007) which is an international standard on test methods for slip resistance in footwear to ensure prevention against slipping. However, one previous study [5] pointed that mechanically measured frictional values do not necessarily represent actual traction performance in sports-specific human movements. There are inconsistent findings between mechanically measured traction coefficient and human traction performance commonly observed in previous studies [6–9]. It can be assumed that these inconsistent findings are potentially due to the fact that test conditions used in conventional mechanical tests are far different from footwear—surface interaction made by players in real-world, sporting situation. This implies the limitation of conventional mechanical tests on the veracity to anticipate actual footwear traction performance in sports-specific scenarios. We aimed to clarify the differences on friction coefficient of footwear used in futsal when mechanically measured in anteroposterior and mediolateral sliding direction.

2 Methodology

2.1 Shoes and Playing Surface

Three types of futsal shoes (Fig. 1: S1, S2 and S3) with different outsole tread grooves were selected for the test. Three pairs of shoes (size 27.0 cm) as shown in Fig. 1, were selected for mechanical test. Each shoe properties and features are described in Table 1. For the sample of playing surface (futsal court material), an area-elastic hardwood surface was selected for this study (Fig. 1). The technical specification (shock absorption and sliding coefficient properties) of the hardwood surface is described in Table 1 as well.

2.2 Mechanical Testing

Traction force (TF) was measured using a mechanical test consisting a 4-degrees of freedom force platform that is controlled by a hydraulic system [10]. Above the platform, an artificial foot made from nylon was statically secured to a profile steel

Fig. 1 The shoes and indoor court material (futsal court) selected in the study

Table 1 Shoes and playing surface properties

Shoe	Mass per shoe (gram)	Sole hardness, Shore A (degree) [manufacturer data]	Playing surface properties [manufacturer data]	
S1	311	57	Shock absorption: 40–55%	Sliding coefficient: 80–110
S2	232	60		
S3	276	60		

frame structure, to which the three types of footwear were tightly secured. To avoid any unwanted movements between the shoe and artificial foot, the shoe was bolted on the anterior and posterior tips of the artificial foot (Fig. 2). The ground reaction forces (Fx, Fy and Fz) were recorded using a force platform (AMTI) that is synchronised to a Qualisys motion analysis system (Qualisys AB, Gothenburg, Sweden) as shown in Fig. 3.

Futsal playing surfaces were tightly bonded on top surface of the force platform using a strong double-sided tape. The moving force platform was controlled using a customized system (Mr. Kick, v. 2.030, Knud Larsen, Aalborg University, Denmark). The platform starts at an initial position below the footwear and upon activation, it will move towards the static footwear to apply the normal load. Upon applying the certain magnitude of normal load, the force platform will move horizontally, creating a backward sliding motion between the top layer of the playing surface and the footwear outsole.

TF was calculated from the mean traction force during 125 ms of steady-state condition. Using TF values and the offset normal force (500 N), available friction coefficient (AFC) was computed. The calculation of AFC is shown in Eq. 1, where

Fig. 2 Illustration of shoe attachment to the artificial foot, **a** anteroposterior, **b** mediolateral sliding orientation

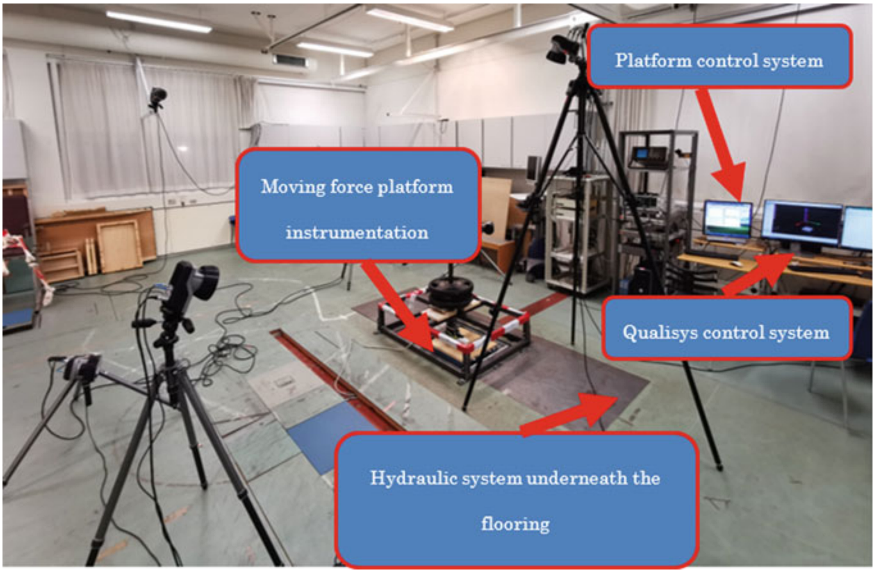

Fig. 3 Test setup for the moving force platform that is synchronized to a Qualisys motion analysis system

AFC was defined as the mean value of friction coefficient during 125 ms of the steady-state condition of the friction coefficient curve [11]. Raw data of the force platform were filtered by 4th order low-pass Butterworth filter at 50 Hz cut-off frequency [12].

$$\text{AFC} = \frac{\sqrt{Fx^2 + Fy^2}}{|Fz|} \tag{1}$$

AFC and TF measurements were carried out with three footwear—playing surface (three shoes, and one playing surface) under dry friction condition. The test condition was set as the followings: (1) the offset normal load = 500 N, (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 and mediolateral) with contact angle at 0° in accordance to the BE EN ISO 13287 test standard. After anteroposterior sliding tests were completed, the artificial foot is rotated 90° from the original position to allow the test to be conducted to the mediolateral side footwear.

2.3 Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 22 (SPP Inc., Chicago, IL, USA). The mean TF and AFC of tested conditions between AP and ML sliding orientations for each shoe were compared using paired sample t-test (two-tailed) and one-way ANOVA repeated measure was used to identify differences between the threeshoes TF and AFC properties. Statistical significance was set at $p < 0.05$.

3 Results

3.1 Traction Force (TF)

There was a significant difference ($p < 0.05$) of TF of S2 shoe in both AP (722 ± 2 N) and ML (664 ± 22 N) direction as compared with other shoes [S1: AP- 672 ± 10 N, ML- 622 ± 30 N; S3: AP- 700 ± 2 N, ML- 605 ± 5 N] as shown in Table 2. It was observed that among the three shoes tested, S2 has produced the highest TF in both sliding orientations ($p < 0.05$). It was also noticed that TF for ML sliding orientation were significantly lower ($p < 0.05$) than AP orientation for all three shoes.

3.2 Available Friction Coefficient (AFC)

Similar to results found in TF, it was observed that among the three shoes tested, S2 has produced the highest AFC in both AP and ML sliding orientations ($p < 0.05$). There was a significant difference ($p < 0.05$) of AFC value when measured in different sliding direction (AP and ML) for all three shoes [S1: AP (M = 1.25, SD = 0.006) and S1: ML (M = 1.00, SD = 0.002), p = 0.0001; S2: AP (M = 1.34, SD = 0.009) and S2: ML (M = 1.31, SD = 0.004), p = 0.0001; S3: AP (M = 1.30, SD = 0.006) and S3: ML (M = 1.11, SD = 0.008), p = 0.001]. In addition, it was observed that S2 shoe was the least affected in terms of reduction of AFC value when compared between AP and ML direction [AFC reduction AP vs. ML: S1- 20% reduction; S2- 2% reduction; S3- 14.6% reduction].

Table 2 Traction force and available friction coefficient mechanical test results under AP and ML sliding orientations

		Traction force [N]		Available friction coefficient (AFC)	
Shoe	Orientation	Mean	SD	Mean	SD
 Shoe 1 (S1)	AP	672 A*	10	1.25 A*	0.006
	Ml	622 A*	30	1.00 A*, †	0.002
		T*		T*	
 Shoe 2 (S2)	AP	722 A*, ‡	2	1.34 A*, ‡	0.009
	ML	664 A*, ‡	22	1.31 A*, ‡	0.004
		T*		T*	
 Shoe 3 (S3)	AP	700 A‡	2	1.30 A‡	0.006
	ML	605 A‡	5	1.11 A*, †	0.008
		T*		T*	

Standard deviation: SD; Paired sample t-test AP versus ML ($p < 0.05$): T*; One-way ANOVA: A; S1 versus S2: *, S1 versus S3: †, S2 versus S3: ‡ ($p < 0.05$)

4 Discussion

This study examined whether there is a significant difference in traction force (TF) and available friction coefficient (AFC) when mechanically measured under different sliding orientation. Three futsal shoes with different shoe outsole tread grooves were mechanically tested in accordance to the BE EN ISO 13287 test standard (AP sliding orientation). In addition, we also tested the shoe and surface interaction under ML sliding orientation, which is not included in the ISO standard. It was found that there was a significant difference in TF as well as AFC properties for shoe and surface interaction measured under different sliding orientation and different shoes. It was also observed that among the three shoes tested, S2 shoe has produced significantly greater TF and AFC as compared to S1 and S3 shoes. In addition, it was identified that there were AFC performance reduction under ML sliding orientation, in which S2 shoe had the least AFC reduction as compared to S1 and S3 shoes.

This study has confirmed that shoe-surface interaction can produce different outcome under different test condition. The shoe outsole property possessed by each shoe may have contributed to these findings. Our mechanical test results are also in line with other studies in the past that involved with human subject functional test, in which have reported that shoe and surface interaction has shown to produced different outcome under different movement task and different shoe properties involving different movement orientation such as straight-line sprint and change of direction movement [5, 13]. In addition, sport such as futsal does require the players to perform various movement [14] and the aspects of traction performance has been shown to significantly influence the functionality and performance of the player [15]. These movements typically will produce different magnitude of the ground reaction force, in which would command different shoe-surface interaction requirement or demand. As frictional properties of surfaces are specific to particular loading patterns [16], the observed discrepancy can be explained by different loading patterns applied during the 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 shoes. Finding from this study also has highlighted the limitation of current footwear test standard in relation to the sports footwear. Sports movements require multi-directional task, and therefore require a more specific test condition as compared to footwear that is use for daily activity.

In terms of the shoe design, it was found that the outsole tread grooves design may have contributed to TF and AFC properties (S2 > S1 and S3). These findings are also in line with other footwear studies that have found the influence of outsoles properties on traction performance which could also affects sports performance [17, 18]. In addition, the range of AFC found in this study (1.00–1.34) was in line with finding from previous study which suggested the traction coefficient for sports shoes are required to achieve minimum threshold of 0.7 to allow enough confidence to perform dynamics task such as change of direction in futsal [19].

However, in this study, only three types of futsal shoes and one playing surface have been tested. Therefore, the study results may not represent the general behaviour of sports footwear and sports surface interaction. More investigation is required for different type of shoes and different materials of playing surface to understand more about sports shoe-surface interaction.

5 Conclusion

Different outcomes of TF and AFC for these sliding directions could potentially due to the different outsole properties which dictates the ground reaction force produced during shoe–surface interaction under different sliding direction. From these findings, it can be suggested that traction performance of sports footwear should be evaluated by multi-directional sliding approach, and conventional one directional evaluation is most likely not adequate to mimic footwear–playing surface traction performance in real world.

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Physical Fitness Profile and Match Analysis of Elite Junior Badminton Players: Case Studies

Wei Sheng Wei Kui, Hui Yin Ler, and Mei Teng Woo

Abstract The purpose of this study was to determine the physical fitness profile, heart rate responses, technical and timing analysis of elite junior badminton players. Four elite junior badminton players (2 males & 2 females; Average age = 17.5 years) with a minimum of 12 h of training per week were included in this study. The players completed a series of fitness testing (cardiorespiratory fitness, speed, agility, upper strength & lower strength, and power) to obtain their physical fitness profile. Heart rate responses were recorded during the matches. Videos of both genders were analyzed using a customized badminton tagging panel with video analysis software. Results showed the fitness levels of male players were better than female players. During the matches, female players demonstrated a greater average % HR compared to male players. Match analysis demonstrated that male single favourite shots were net (31.68%) and smash (20.04%), while female favourite shots were clear (25.43%) and drop (19.58%). The winning shots for the males were mostly from smash, while the females' winning shots were from drop. The results of the study provide an insight to the coaches to develop effective training plans for junior players based on gender. (197 words).

Keywords Technical analysis · Heart rate · Timing motion analysis

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1 Introduction

Badminton, one of the most popular sports in Malaysia after football. The major achievement was winning the Thomas Cup back in 1992. However, they have not been able to get the same performance results in the Thomas Cup ever since. The unbalanced team, which relies on specific singles and doubles could be the major disadvantage for the team event at Thomas Cup. To strengthen the team event in the major badminton games such as Thomas Cup and SEA Games, it is particularly important to build the pool of badminton athletes through an effective junior development programme. This allows greater transition and wider net for athlete's selection for team event (e.g., Thomas Cup).

In a typical development programme and coaching plan, it is important for coaches and sports scientists to consider the physiological requirements, and the tactical and technical aspects of a badminton match. Heart rate monitoring is important from a physiological perspective because it is an indicator that reflects body metabolism and is widely applied to sports training practice. It provides a comprehensive reflection of the physiological conditions in vivo during sport movement and of the real-time sports intensity during training and competition (Chi, 2014). A few researchers reported that an average HR_{max} value of 190.5 beats.min^{-1} in elite males and 193 beats.min^{-1} in elite females during tournaments [1–5]. While male juniors have an average of 198 beats.min^{-1} of HR_{max} and female juniors have an average of 199 beats.min^{-1} of HR_{max} during the bleep test. To the best of our knowledge, no study has reported the heart rate responses of junior players during tournaments.

A typical badminton match consists of repeated bouts of high intensity movements with short periods of rest [5]. The primary energy system involved during the match is the anaerobic system, the alactic anaerobic system [5–8]. Moreover, Leong and Krasilshchikov [9] found that elite players required a higher aerobic capacity than junior elite players in the international tournament (1449.2 s vs. 1066.3 s) with higher intensity (12.3 vs. 8.7 shots per rally). The understanding of physiological demand during badminton matches would help coaches develop better strategies for both tactical plays between the sets as well as between the games.

Match analysis has been commonly used in analyzing the technical aspects of team sports such as water polo, handball [10], basketball [11] and soccer [12]. Recently, an increasing interest has been observed in using video-based analysis in badminton [13]. Technical analysis and timing analysis, also known as temporal structure, are the typical match analysis used in sports. Timing motion analysis is known as playing time, rally time, pause time and effective playing time in a match. While the technical analysis corresponds to the quantification of the offensive and defensive actions performed by the athletes [14]. The overall match related analysis data could provide insights to enhance coaches' understanding on the baseline fitness and important stroke requirements of a match [13, 15]. Previous studies showed that Men singles' most favorite shots in the last shot of the rallies was smash (29.1%) and drive (6.3%) [16–18]; while for women, singles drop was the favorite shot of the last rallies