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Hydrodynamic Analysis of Bi-finswimming Relay Diving Athletes in Central Java Province

Sungkowo[1ABCDE], Tandiyo Rahayu[1ABCDE], Bambang Widjanarko[2ABCDE], Taufiq Arif Setyanto[2ABCDE], Dewangga Yudhistira[3ABCD]

[1]Faculty of Sport Science, Universitas Negeri Semarang, Semarang, Indonesia
[2]Research Centre for Hydrodynamics Technology-National Research and Innovation Agency
[3]Faculty of Sport Science and Health, Universitas Negeri Surabaya, Indonesia

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Corresponding Author: Dewangga Yudhistira, dewanggayudhistira@unesa.ac.id

Abstract

Background and Study Aim. Analysis must be conducted so that dive comprehension and learning become more effective and efficient. Speed testing and bi-finswimming movement approach in diving, on the other hand, necessitate specialised equipment. Furthermore, studies on hydrodynamic analysis in diving are still scarce in Indonesia. Thus, the objective of this research was to examine the hydrodynamics of bi-finswimming 4x100 metre bi-finswimming relay athletes.

Material and methods. The descriptive quantitative research method was employed, along with a survey and a correlational methodology.Document analysis approaches, interviews as problem rationalisation and field tests were used to collect data. Four diving athletes from the National Sports Week competition participated in the study. A dynamometer and a Qualisys underwater camera were among the research tools. Path analysis as a data analysis technique with SPSS application version 23.

Results. According to the survey results, bi-fin swimmers have varied techniques that fall into three categories: effective, less effective, and ineffective. The correlational results revealed that the athlete's body position to the left is not significant to speed, the athlete's body position to the right is significant to speed, the athlete's sliding position with both hands forward is not significant to speed, the athlete's recovery position with the left hand is significant for speed, and the position of the recovery athlete with the right hand is significant for speed.

Conclusions. Understanding and mastering the bi-finswimming style can reduce drag, resulting in faster speeds. The authors expect that this study will be valuable as a resource for diving coaches and athletes. Future researchers are likely to employ a bigger sample size so that the data acquired can be more broadly generalised.

Key words: hydrodynamic analysis of diving athletes, bi-finswimming technique, resistance test, best time relay.

Анотація

Гідродинамічний аналіз спортсменів, які беруть участь в естафетному плаванні у двох ластах у провінції Центральна Ява

Сунгково, Тандіо Рахаю, Бамбанг Віджанарко, Тауфік Аріф Сетянто, Деванга Юдхістіра

Передумови та мета дослідження. Аналіз повинен проводитися таким чином, щоб розуміння та навчання дайвінгу стали більш ефективними та дієвими. З іншого боку, тестування швидкості та підхід до руху у двох ластах у дайвінгу потребують спеціалізованого обладнання. Крім того, дослідження з гідродинамічного аналізу в дайвінгу досі рідкісні в Індонезії. Таким чином, метою даного дослідження було вивчення гідродинаміки спортсменів естафети 4x100 метрів у двох ластах.

Матеріал і методи. Використовувався метод кількісного описового дослідження, а також опитування та кореляційна методологія. Для збору даних використовувалися підходи аналізу документів, інтерв'ю як раціоналізація проблем та польові випробування. У дослідженні взяли участь чотири спортсмени-дайвери зі змагань Національного спортивного тижня. Серед інструментів дослідження були динамометр та підводна камера Qualisys. Аналіз траєкторії як метод аналізу даних із додатком SPSS версії 23.

Результати. Згідно з результатами опитування, плавці у двох ластах використовують різні техніки, які поділяються на три категорії: ефективні, менш ефективні та неефективні. Кореляційний аналіз показав, що положення тіла спортсмена зліва не має значний вплив для швидкості, положення тіла спортсмена справа має значний вплив для швидкості, ковзаюче положення тіла спортсмена з обома руками вперед не має значного впливу для швидкості, положення спортсмена при відпочинку з лівої сторони має значний вплив для швидкості і положення спортсмена при відпочинку правої сторони має значний вплив для швидкості.

Висновки. Розуміння та освоєння стилю плавання у двох ластах може зменшити опір, що призведе до вищої швидкості. Автори очікують, що це дослідження буде цінним ресурсом для тренерів та спортсменів з дайвінгу. Майбутні дослідники, ймовірно, будуть використовувати більший розмір вибірки, щоб отримані дані можна було ширше узагальнити.

Ключові слова: гідродинамічний аналіз, спортсмени-пірнальники, техніка плавання у двох ластах, тест на опір, естафета на найкращий час.

Introduction

Diving is inextricably linked to technical and physical factors [1]. According to the literature research, sports associated with achievement have many factors that must be addressed to reach high achievement [2]. Furthermore, the standard for becoming a professional athlete is based on several factors [3]. According to another study, psychological, physiological, physical, and technical factors all influence an athlete's performance [4]. Dive techniques and physics must be mastered and developed to become perfect [5]. The finswimming technique is one of the most significant in diving [6]. According to research, diving competitors who grasp the finishing technique will be able to minimise drag, reduce fatigue, and provide effective propulsion [7]. Surface finswimming, apnea finswimming, immersion finswimming, and bi-finswimming are the four types of finswimming techniques [8].

Based on observations at the National Sports Week (PON) competition, the Central Java team won sixth place in the women's 4 × 100-metre bi-finswimming relay [9]. Each person in this relay number uses a different technique. Due to the opponent's water waves and the athlete's different techniques, their performance falls significantly short of that of competitors from other provinces. These data lead us to the conclusion that finswimming divers use a variety of technique styles, some of which are effective and others which are not. However, only analysis based on empirical data can serve as proof. An essential study for a more thorough analysis is the finswimming technique. This is because athletes will be able to minimise resistance and produce efficient propulsion by mastering these techniques. This fundamental technique needs to be explained, where the trainer must be able to identify the error's position and choose the most appropriate technique.

Technical analyses on diving must be performed, and as time passes, these analyses must incorporate modern aspects and not just follow the lead of one scientific field. The authors will conduct a hydrodynamics-based analysis. Incompressible liquids are particularly said to be impacted by both internal and exterior forces by the scientific discipline of hydrodynamics, which studies fluid motion [10]. Studies that are pertinent to this issue involving MEMS Sensors Applied in Finswimming Movement Analysis have been located [11]. The measuring device is intended to assess leg acceleration, the differential in angular velocity between elite and sub-elite athletes, and finswimming at a distance of 50 metres. The findings showed that the elite and sub-elite athlete groups had substantial differences and that elite athletes were 20% better at movement methods [12].

Research by Mejia-Gallon in 2024 examined the effectiveness of swimming techniques involving variations in speed, stroke index, and thermodynamic estimates. The study revealed an improvement in swimming efficiency [13]. Although the aforementioned research is used as a reference because it is pertinent, there are differences in the techniques, testing apparatus, samples, and research locations. As a result, the author's research treats these variations as original. Additionally, there hasn't been much research done on this chapter in Indonesia. Therefore, it is expected that the research will be useful for academics and athletes, particularly divers. Through the Hydrodynamics Technology Research Centre (PRTH), the National Research and Innovation Agency (BRIN) and Semarang State University have collaborated on this study.

The objectives of this study are to (1) conduct a survey analysis of the hydrodynamics of finswimming motion on athletes diving in the 4 x 100-metre bi-finswimming relay using hydrodynamic analysis consisting of a resistance dynamometer and a quality tracking sensor and (2) perform a hydrodynamic correlational analysis of bi-finswimming relay speed based on field observations and analysis of documents in the form of pertinent articles.

Material and methods

Participant

The quantitative descriptive research method was utilised, together with a survey and a correlational approach [14]. The variables of this study are bi-finswimming motion techniques (X1), resistance tests (X2), and best-time bi-finswimming relay (Y1). This study included four female bi-finswimming relay diving participants from the National Sports Week (PON). A survey was used to obtain information. The tests were carried out at the Agency for the Assessment and Application of Technology's (BPPT) hydrodynamics laboratory or the BRIN hydrodynamics technology centre in Surabaya, Indonesia. The following figure shows the pattern of interrelationships between research variables.

Procedure

The research instruments consist of a resistance dynamometer and a Qualisys underwater camera [15]. Path analysis was the data analysis method used. The purpose of this study is to examine the relationship between the bi-finswimming technique, which is impacted by waves, and the athletes' resistance to the speed of the 4x 100-metre bi-finswimming relay. The Qualisys under water camera instrument has a calibration which can be seen in tables 1-2 as follows**.**

The instrumentation analyses drag (including passive and active drag), as well as a variety of Bi-finswimming techniques relating to anthropometry, swimming kinematics, and motion efficiency. In addition, the diving athletes were subjected to three hydrodynamic analysis experiments: (1) water conditions with no waves, (2) water conditions with regular waves and a wave height of 5

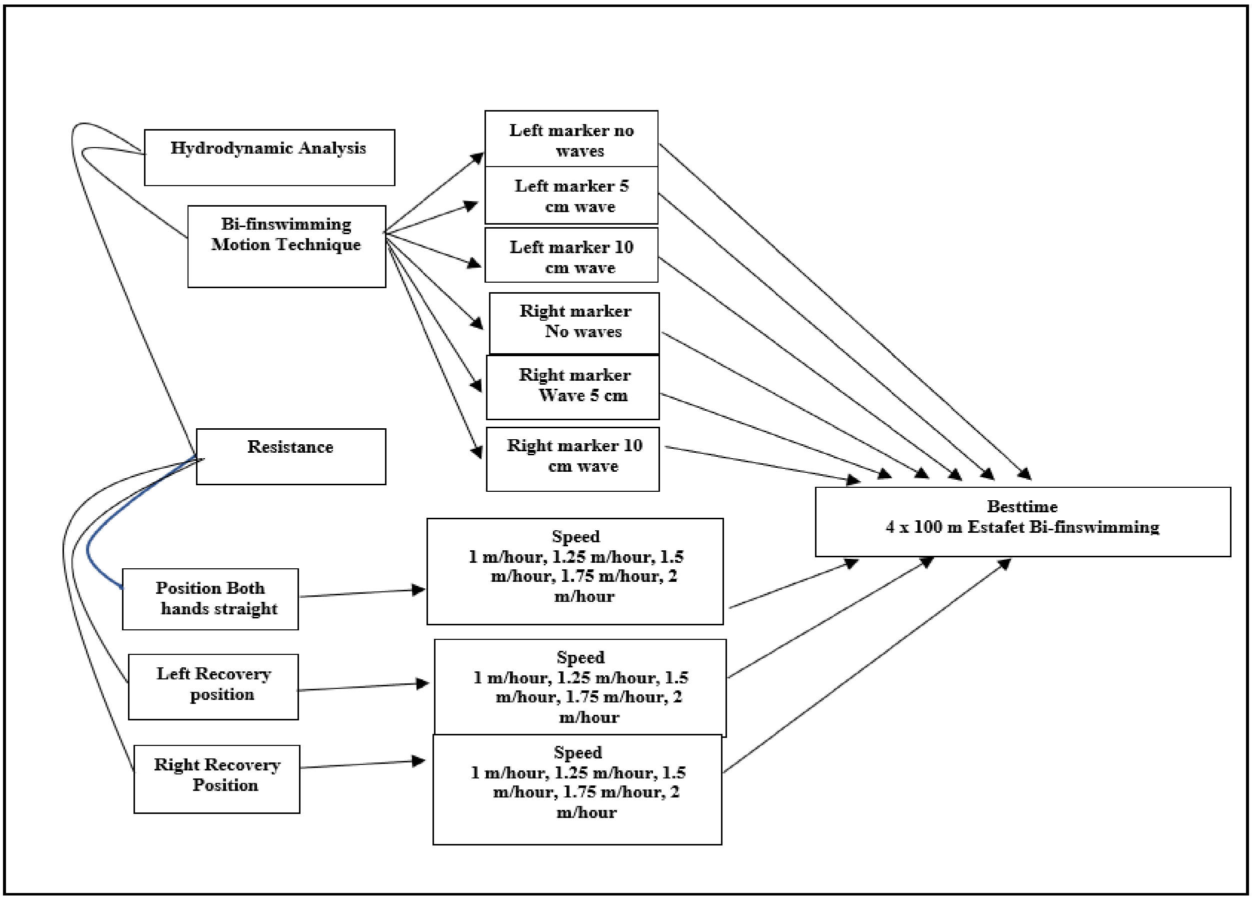

Figure 1. **The pattern of interrelationships between variables. Source: Personal documentation**

Table 1. **Calibration results of the camera**

Camera	X (mm)	Y (mm)	Z (mm)	Points	Avg. residual (mm)	Calibration passed
01	-2859.27	4766.74	-13.89	1370	0.72087	Valid
02	368.40	5032.20	-93.18	1376	0.48534	Valid
03	2439.49	4818.11	-61.11	1456	0.60806	valid

Table 2. Resistance Dynamometer Calibration

Input mass (kg)	Input (N)	Output (N)	Out after zero (N)	Delta (N)
Push Validation				
0	0	-6,7	0,0	0,0
5	49	-55,5	-48,8	-0,2
7	68,6	-75,1	-68,4	-0,2
17	166,6	-173,0	-166,2	-0,4
12	117,6	-124,0	-117,3	-0,3
5	49	-55,5	-48,8	-0,2
0	0	-6,7	0,0	0,0
Pull Validation				
0	0	22,6	0,0	0,0
5	49	71,6	49,1	0,1
10	98	120,7	98,2	0,2
15	147	169,8	147,2	0,2
20	196	218,8	196,3	0,3
15	147	169,8	147,3	0,3
10	98	120,8	98,2	0,2
5	49	71,8	49,2	0,2
0	0	22,6	0,1	0,1

cm, and (3) water conditions with regular waves and a wave height of 10 cm. To be clearer can be seen in figure 2 as follows:

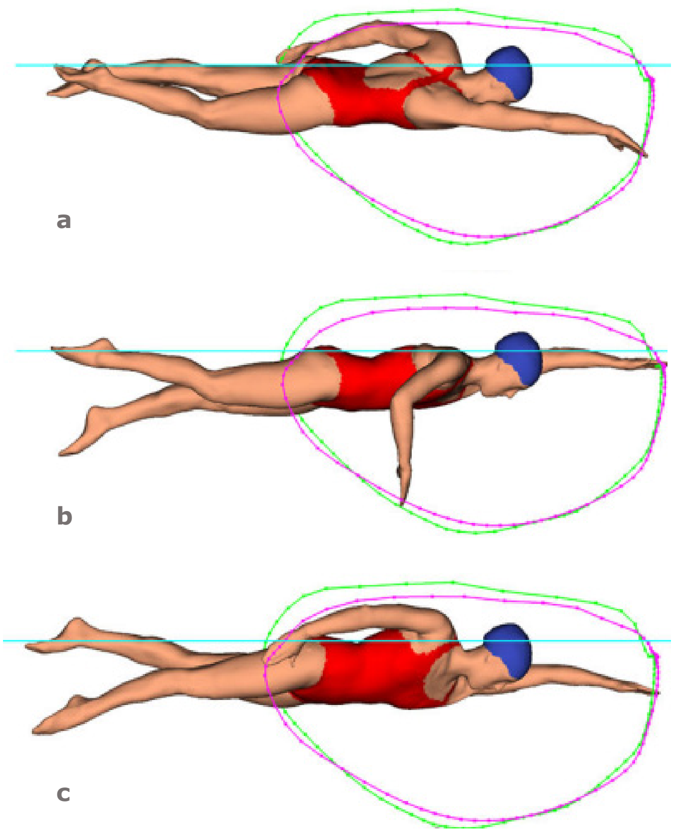

Figure 2. Testing the bi-finswimming motion technique with the Qualisys underwater camera. Source: Cohen 2018 (19)

In arm movements, the bi-finswimming number is the same as the crawl-style swimming movements. Arm movement is divided into several movements, namely entry and alignment (entering the arm), stroke (down and catch sweep, insweep, and upsweep), and recovery [16]. Researchers interpret the downward sweep and insweep as movements with a strong impulse for onward movement [17,18]. The angle of the bottom stroke is 90° - 120° (right and left arm) [18]. whereas the angle of the inside stroke is 40° - 60° (right and left arm). The limb movement in the bi-finswimming number is the same as the crawl-type swimming action; the difference is that the bi-finswimming number uses fins. In this situation, the athlete alternately moves both legs up (upbeats) and down (downbeats), with the lower leg bending at the knee and rising at an angle of 30-400 (right and left leg) [19]. The criteria for bi-finswimming technique are presented in table 3 and resistance testing can be seen in figure 2 as follows [19] :

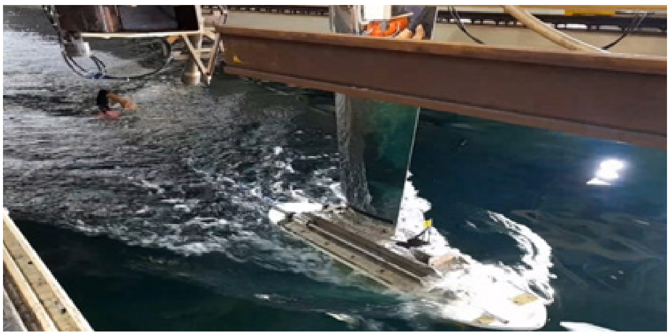

Figure 3. Testing of Dynamometer Resistance Instruments. Source: Personal documentation

Table 3. **Criteria for the bi-finswimming technique**

No	Leg Angle During Upward Movement	Criteria
1	Under 19⁰	Ineffective
2	20⁰ - 29⁰	Less effective
3	30⁰ - 40⁰	Effective
4	41⁰ - 50⁰	Less effective
5	51⁰ - and above	Ineffective

No	Downsweep Angle	Criteria
1	Under 69⁰	Ineffective
2	70⁰ - 89⁰	Less effective
3	90⁰ - 120⁰	Effective
4	121⁰ - 140⁰	Less effective
5	141⁰ - and above	Ineffective

No	Insweep Angle	Criteria
1	Under 19⁰	Ineffective
No	**Insweep Angle**	**Criteria**
2	20⁰ - 39⁰	Less effective
3	40⁰ - 60⁰	Effective
4	61⁰ - 80⁰	Less effective
5	81⁰ - and above	Ineffective

In finswimming athletes, the resistance dynamometer must be capable of minimising resistance or water resistance that can impede the body's pace [20, 21]. The presence of impediments is caused by the shape of the water flow and the body shape of fin-swimmers. There are three test positions: (1) forward slide, (2) right arm recovery, and (3) left arm recovery.

Statistical Analysis

The data analysis technique using Path analysis is a form of multiple regression analysis. This analysis is guided by a path diagram to conceptualize problems or test complex hypotheses. In this way, the direct relationship between the independent variable and the dependent variable can be calculated. This analysis is used as a method to identify how the direct and indirect effects of one or more variables on other variables. Path analysis is used when researchers want to identify relationships between more complex variables that cannot be done with multiple regression analysis. The good thing about path analysis is its ability to estimate parameters so that it can be used to identify all possible causal relationships in the variables used in the model, and can analyze the total effect of exogenous variables and break it down into direct effects and indirect effects. statistical analysis is assisted with the SPSS 23 application.

Result

Results of hydrodynamic testing on bi-finswimming relay athletes

The results of the hydrodynamic analysis of bi-finswimming numbers for water conditions without waves, 5 cm waves, 10 cm waves, and resistance tests on athletes numbers 1 to 4, Presented in Table 4 as follows:

Based on the table above, overall athletes number 1 to 4 from the right and left marker positions get the results of the bottom sweep angle, the inner sweep angle and the leg angle get less effective, effective and ineffective results. This shows that individuals have different abilities, then specifically also seen from different angles also have different abilities, so it is necessary to observe specifically and individually on aspects of technique and physical conditions. More clearly presented in the discussion section.

Results of resistance testing on bi-finswimming relay athletes

The results of resistance testing analysis in bi-finswimming relay number diving athletes are presented in table 5 as follows:

Interpretation of results Athlete number 1

According to the table above, the results of the dynamometer resistance test in position "A" or position with both hands straight found that a speed of 1 m/hour produces a resistance force of 2.916 kg, a speed of 1.25 m/hour produces a resistance force of 4.752 kg, a speed of 1.50 m/hour produces a resistance force of 6.863 kg, a speed of 1.75 m/hour produces a resistance force of 9.350 kg, and a speed of 2 m/hour produces a resistance force of 13.203 kg.

In the "B" position or left-hand recovery, it was found that a speed of 1 m/hour resulted in a resistance force of 5.009 kg, a speed of 1.25 m/hour resulted in a resistance force of 6.159 kg, a speed of 1.50 m/hour resulted in a resistance force of 7.934 kg, a speed of 1.75 m/hour produces a resistance force of 11.367 kg, a speed of 2 m/hour produces a resistance force of 16.298 kg.

In the "C" position or the right-hand recovery, it is found that a speed of 1 m/hour produces a resistance force of 5.068 kg, a speed of 1.25 m/hour produces a resistance force of 5.928 kg, a speed of 1.50 m/hour produces a resistance force of 8.228 kg, a speed of 1.75 m/hour produces a resistance force of 10.067 kg, a speed of 2 m/hour produces a resistance force of 15.265 kg.

Interpretation of results athlete number 2

Based on the table above which presents the results of the dynamometer resistance test, it is known that in the "A" position or both

Table 4. **Results of analysis of bi-finswimming motion techniques on athletes number 1-4**

	No.	Wave Conditions	Marker Position	Downsweep Angle (⁰)	Insweep Angle (⁰)	Leg Angle (⁰)
Number 1 athlete	1	No Waves	Left	129 (Less effective)	127 (Ineffective)	40 (Effective)
	2	5cm wave		134 (Less effective)	140 (Ineffective)	39 (Effective)
	3	10cm wave		145 (Ineffective)	154 (Ineffective)	18 (Ineffective)
	4	No Waves	Right	159 (Ineffective)	158 (Ineffective)	53 (Ineffective)
	5	5cm wave		147 (Ineffective)	154 (Ineffective)	46 (Less Effective)
	6	10cm wave		146 (Ineffective)	152 (Ineffective)	44 (Less Effective)
Number 2 athlete	1	No Waves	Left	147 (Ineffective)	144 (Ineffective)	29 (Less Effective)
	2	5cm wave		148 (Ineffective)	146 (Ineffective)	29 (Less Effective)
	3	10cm wave		144 (Ineffective)	142 (Ineffective)	34 (Effective)
	4	No Waves	Right	119 (Effective)	133 (Ineffective)	40 (Effective)
	5	5cm wave		120 (Effective)	132 (Ineffective)	43 (Less Effective)
	6	10cm wave		144 (Effective)	128 (Ineffective)	26 (Less Effective)
Number 3 athlete	1	No Waves	Left	154 (Ineffective)	151 (Ineffective)	31 (Effective)
	2	5cm wave		150 (Ineffective)	146 (Ineffective)	28 (Less Effective)
	3	10cm wave		150 (Ineffective)	147 (Ineffective)	33 (Effective)
	4	No Waves	Right	159 (Ineffective)	159 (Ineffective)	35 (Effective)
	5	5cm wave		155 (Ineffective)	158 (Ineffective)	17 (Ineffective)
	6	10cm wave		152 (Ineffective)	155 (Ineffective)	31 (Effective)
Number 4 athlete	1	No Waves	Right	105 (Effective)	105 (Ineffective)	8,1 (Ineffective)
	2	5cm wave		100 (Effective)	95 (Ineffective)	9,3 (Ineffective)
	3	10cm wave		103 (Effective)	94 (Ineffective)	7,3 (Ineffective)
	4	No Waves	Left	107 (Effective)	112 (Ineffective)	26 (Less effective)
	5	5cm wave		112 (Effective)	117 (Ineffective)	24 (Less effective)
	6	10cm wave		109 (Effective)	119 (Ineffective)	18 (Ineffective)

hands straight, a speed of 1 m/hour produces a resistance force of 3.101 kg, a speed of 1.25 m/hour produces a resistance force of 4.441 kg, a speed of 1 .50 m/hour produces a resistance force of 5.213 kg, a speed of 1.75 m/hour produces a resistance force of 6.166 kg, a speed of 2 m/hour produces a resistance force of 9.463 kg.

In the "B" position or the left-hand recovery, the following results are found: a speed of 1 m/hour produces a resistance force of 3.679 kg, a speed of 1.25 m/hour produces a resistance of 4.854 kg, a speed of 1.50 m/hour produces a resistance force of 5.619 kg, a speed of 1.75 m/hour produces a resistance force of 7.188 kg, a speed of 2 m/hour produces a resistance force of 10.747 kg.

A speed of 1 m/hour produces a resistance force of 3.691 kg in the "C" position or Recovery right hand, a speed of 1.25 m/hour produces a resistance force of 5.260 kg, a speed of 1.50 m/hour produces a resistance force of 6.888 kg, a speed of 1.75 m/hour produces a resistance force of 9.083 kg, and a speed of 2 m/hour produces a resistance force of 11.753 kg.

Interpretation of results athlete number 3

Based on the table above, testing the dynamometer resistance in position "A" or both hands straight found that a speed of 1 m/hour produces a resistance force of 2.637 kg, a speed of 1.25 m/hour produces a resistance force of 3.501 kg, a speed of 1.50 m/ hour produces a resistance force of 4.927 kg, a speed of 1.75 m/hour produces a resistance force of 7.193 kg, a speed of 2 m/hour produces a resistance force of 9.135 kg.

In the "B" position or Recovery of the left hand, found that a speed of 1 m/hour produces a resistance force of 3.960 kg, a speed of 1.25 m/hour produces a resistance force of 5.287 kg, a speed of 1.50 m/hour produces a resistance force of 6.498 kg, a speed of 1.75 m/hour produces a resistance force of 8.531 kg, a speed of 2 m/hour produces a resistance force of 11.542 kg.

In the "C" position or right-hand recovery, it is found that a speed of 1 m/hour produces a resistance force of 3.649 kg, a speed of 1.25 m/

Table 5. Results of resistance testing in relay number diving athletes

	No	Speed	Position "A" both hands straight (Final Force)	Position "B" Left-hand recovery (Final Force)	Position "C" Right-hand recovery (Final Force)
Number 1 athlete	1	1,00	2,916	5,009	5,068
	2	1,25	4,752	6,159	5,928
	3	1,50	6,863	7,934	8,228
	4	1,75	9,350	11,367	10,067
	5	2,00	13,203	16,298	15,265
Number 2 athlete	1	1,00	3,101	3,679	3,691
	2	1,25	4,441	4,854	5,260
	3	1,50	5,213	5,619	6,888
	4	1,75	6,166	7,188	9,083
	5	2,00	9,463	10,747	11,753
Number 3 athlete	1	1,00	2,637	3,960	3,649
	2	1,25	3,501	5,287	4,717
	3	1,50	4,927	6,498	6,262
	4	1,75	7,193	8,531	8,427
	5	2,00	9,135	11,452	11,274
Number 4 athlete	1	1,00	2,615	3,795	3,498
	2	1,25	3,470	4,925	4,495
	3	1,50	4,370	5,476	5,353
	4	1,75	5,671	7,114	7,376
	5	2,00	8,139	10,291	10,846

Table 6. Results of hydrodynamic analysis of biffins relay speed

Hydrodynamics with Speed	Left		Right		A position		B position		C Position	
	r	sig.	R	sig.	r	sig.	R	sig.	r	sig.
	0,400	0,600	1.000**	0,010	0,800	0,200	1.000**	0,010	0,800	0,200

hour produces a resistance force of 4.717 kg, a speed of 1.50 m/hour produces a resistance force of 6.262 kg, a speed of 1.75 m/hour produces a resistance force of 8.427 kg, a speed of 2 m/hour produces a resistance force of 11.274 kg.

Interpretation of results athlete number 4

Based on the aforementioned table, it was discovered that testing the dynamometer resistance in position "A" or with both hands straight results in a resistance force of 2.615 kg for a speed of 1 m/hour, 3.470 kg for a speed of 1.25 m/hour, 4.370 kg for a speed of 1.50 m/hour, 5.671 kg for a speed of 1.75 m/hour, and 8.139 kg for a speed of 2 m/hour.

In the "B" position or recovery of the left hand it is found that a speed of 1 m/hour produces a resistance force of 3.795 kg, a speed of 1.25 m/hour produces a resistance force of 4.925 kg, a speed of 1.50 m/hour produces a resistance force of 5.476 kg, a speed of 1.75 m/hour produces a resistance force of 7.114 kg, a speed of 2 m/hour produces a resistance force of 10.291 kg.

In the "C" position or Recovery of the right hand it is found that a speed of 1 m/hour produces a resistance force of 3.498 kg, a speed of 1.25 m/hour produces a resistance force of 4.495 kg, a speed of 1.50 m/hour produces a resistance force of 5.353 kg, speed of 1.75 m/hour produces a resistance force of 7.376 kg, speed of 2 m/hour produces a resistance force of 10.846 kg.

Correlation results of hydrodynamic analysis on bi-finswimming relay speed

The results of the correlation of hydrodynamic analysis to the speed of the bi-finswimming relay are presented in table 6 as follows.

Based on the table above, hydrodynamic analysis with a bi-finswimming relay speed 4x 100 meters has an R-value of 0.400 and a significance

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value of 0.600 > 0.05 means that from the hydrodynamic analysis, it is concluded that the left side of the athlete's body position does not significantly affect speed. Hydrodynamic analysis with a 4x100 meter bi-finswimming relay speed, the R-value of 1,000 and a significance value of 0.010 <0.05 indicate that the right side of the athlete's body position has a significant effect on speed.

Based on the above table, it can be concluded that the hydrodynamic analysis of position A of the athlete sliding with both hands forward has no significant impact on speed because the speed of the 4x100 metre bi-fin swimming relay had an R-value of 0.880 and a significance value of 0.200 > 0.05. The hydrodynamic study of position B in left-hand recovery athletes has significant effects on speed, as shown by the hydrodynamic analysis with a bi-finswimming relay speed of 4x100 metres with an R-value of 1.00 and a significance value of 0.010<0.05. Furthermore, hydrodynamic analysis with a 4x100 meter bi-finswimming relay speed with an R-value of 0.800 and a significance value of 0.200 > 0.05 means that the hydrodynamic analysis of the athlete's C position or right-hand recovery has no significant effect on speed.

Discussion

The results of the survey analysis on four athletes found that in the bi-finswimming motion, the angle of the down sweep, insweep and legs differs according to the criteria of "effective", "less effective" and ineffective. Resistance test results on four athletes in position "A" (both arms straight),

position "B" (left-hand recovery), position "C" (right-hand recovery using a speed of 1m/hour, 1.25 m/hour, 1/50 m/hour, 1.75 m/hour, 2 m/hour) shows that the four athletes have different resistance strength.

The results of the hydrodynamic analysis with a bi-finswimming relay speed of 4x100 meters found a significance value of 0.600 > 0.05. As a result, it is possible to conclude that the hydrodynamic analysis of the athlete's body posture to the left has no bearing on speed. This is because athletes adopt ineffective techniques. The influence of waves determines changes in motion technique, and the average athlete's strength when pulling the arms and legs is underpowered, so if there is wave influence from the left, the athlete will not be able to maintain the technique properly. In keeping with the study conducted by Barbosa et al regarding young swimmers' sprint performance, disparities were discovered, particularly in shoulder flexibility, anthropometry, stroke frequency, and speed. According to the findings of various experts, the capacity to generate a propulsive force and minimise hydrodynamic resistance while swimming is greatly impacted by speed and strength. Fernandes et al. discovered that swimming athletes with high variability in hydrodynamics improved in the initial and final tests, but not considerably [22]. Given that the number of samples used is small, the impact of the data obtained is minimal [23].

The hydrodynamic study of the athlete's right-hand body position is significant for speed, according to the results of the hydrodynamic analysis with bi-fin swimming relay speed 4x100 metres, which obtained a significance value of 0.010 < 0.05. This is because athletes have techniques that are considered to be efficient. To withstand the influence of the waves, every athlete uses sound techniques. Athletes also have stronger arms and legs when they are in the proper position. Reducing resistance and boosting speed are related to technology that creates efficient ways. According to another study, at a given speed, amplitude and frequency can be inversely proportional to one another, resulting in a well-correlated relationship with average speed [24].

The hydrodynamic study of position "A" of the athlete sliding with both hands forward is not important to speed, according to the results of the hydrodynamic analysis with the 4x100 metre bi-fin swimming relay speed, which got a significance value of 0.200 > 0.05. There is more resistance when the two hands are sliding in the straight-ahead posture. Additionally, it creates obstacles that slow down the athlete's pace when the right and left shoulders are parallel to the water's surface. Each athlete has a varied level of strength, which naturally causes the two shoulders to be wider than their corresponding levels of strength. This has an impact on the speed rate. Additionally, the research sample was modest, which also affected the outcomes of the data collected [24].

Concerning the 4x100 metre bi-fin relay speed, position "B" for the left-hand recovery athlete, the hydrodynamic analysis results received a significance value of 0.010<0.05, indicating that it significantly affects speed. The recovery of the left hand demonstrates that the average athlete has sound technique since his arm is flexible enough to allow for the largest movement and the least amount of resistance. Relevant research supports this study's finding that the crawl-type stroke arm-stroke cycle trial showed no significant change and that the recovery phase did not significantly slow down the speed [25]. Another study also stated that there was no significant impact of fluid flow on the coordination of inter-circle variability of swimmers both up and down during the cycle and stroke phase [26].

The results of the hydrodynamic analysis with the 4x100 meter bi-finswimming relay speed, position "C" of the right-hand recovery athlete obtained a significance value of 0.200>0.05, meaning that it has no significant effect on speed.

This is because the right arm's recovery technique is weak and its level of flexibility cannot be deemed to be effective, which presents a significant challenge. A higher number of samples are required to enable generalisation because a small sample yields less ideal data[9].

Conslusion

Based on the results and discussion described, it is concluded that the correlation (1) hydrodynamic analysis of the athlete's body position on the left is insignificant to speed, (2) hydrodynamic analysis of the athlete's body position on the right is significant to speed, (3) hydrodynamic analysis of position "A" athletes glide with both hands forward is insignificant to speed, (4) hydrodynamic analysis of position "B" athletes left-hand recovery is significant to speed, (5) hydrodynamic analysis of position "C" athletes right-hand recovery is significant to speed. That the survey of bi-finswimming athletes has different technical styles in the effective, less effective, and ineffective categories. Therefore this can be an evaluation of the coaches for their athletes in terms of the effectiveness of the use of techniques and physical aspects of speed. In addition, this related research is still minimal in Indonesia so it becomes a novelty in this study. However, understanding the limitations of this study is very important, the limitations of this study are in terms of methods that are less complex, only conducting survey analysis, and relatively small research samples so that the results cannot be generalized properly. Therefore, it is hoped that further research will improve the limitations in this study so that the research will be better.

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Authors details

Sungkowo
https://orcid.org/0000-0002-2266-8074,
sungkowo@mail.unnes.ac.id
Department of Sport Coaching Education, Faculty of Sport Sciences, Semarang State University, Semarang, Indonesia

Tandiyo Rahayu
https://orcid.org/0000-0002-8690-6377,
tandiyorahayu@mail.unnes.ac.id
Department of Sport Coaching Education, Faculty of Sport Sciences, Semarang State University, Semarang, Indonesia

Bambang Widjanarko
https://orcid.org/0009-0001-5883-6957,
bamb017@brin.go.id
Research Center for Hydrodynamics Technology – BRIN Jl. Hidrodinamika, Keputih, Kec. Sukolilo, Surabaya, East Java 60112

Taufiq Arif Setyanto
https://orcid.org/0009-0005-8039-3901,
tauf002@brin.go.id
Research Center for Hydrodynamics Technology – BRIN Jl. Hidrodinamika, Keputih, Kec. Sukolilo, Surabaya, East Java 60112

Dewangga Yudhistira
https://orcid.org/0000-0002-4194-1283,
dewanggayudhistira@unesa.ac.id
Faculty of Sport Science and Health, Surabaya State University, Indonesia, UNESA Campus, Lidah Wetan, Kec. Lakarsantri, Surabaya, East Java 60213