2024, Retos, 57, 684-691

Sensor-based scoring system for the fighting category in Pencak Silat
Sistema de puntuación basado en sensores para la categoría de combate en Pencak Silat

*Nurul Ihsan, *Yulkifli, *Ahmaddul Hadi, *Yohandri, *Deby Tri Mario, **Novadri Ayubi, ***Aydin Karacam, ****Zsolt Németh, *****Bekir Erhan Orhan
*Universitas Negeri Padang (Indonesia), **Universitas Negeri Surabaya (Indonesia), ***Bandırma Onyedi Eylül University (Türkiye), ****University of Pécs (Hungary), *****Istanbul Aydın University (Türkiye)

Abstract. The scoring system which still focuses on the jury's observations is one of the problems with Pencak Silat not being competed at the Olympics, so a technology-assisted solution is needed. This research aims to develop a scoring system based on sensor technology installed on body protectors for the fighting category in Pencak Silat. This research consists of tool design, feasibility testing, and implementation. The equipment components installed on the body protector include flex sensors, foam, an RFID reader, an Arduino, and NRF24L. A total of 9 experts were assigned to assess its feasibility, namely information and technology experts (n_1=3), instruments experts (n_2=3), and Pencak Silat experts (n_3=3). Then, 120 male (n_1=70; 18.67±3.28 years) and female (n_2=50; 18.69±3.52 years) Pencak Silat athletes were involved in field trials. Data were analyzed using Aiken's V index, ICC, ANOVA, and independent samples t-test. The results showed that the average V index was 0.778; ANOVA and ICC also showed that there were no differences in assessments between experts (p>0.05) with very high reliability (p<0.05). Then, the independent sample t-test analysis results showed no significant differences between the two assessment systems (p>0.05). In conclusion, this tool can be used as an alternative scoring system for the fighting category in Pencak Silat, so it is hoped that it will be helpful to the jury and Pencak Silat practitioners in facilitating their performance in providing objective and transparent assessments.
Keywords: martial arts, body protector, technology

Resumen. El sistema de puntuación que todavía se centra en las observaciones del jurado es uno de los problemas por los que el Pencak Silat no compite en los Juegos Olímpicos, por lo que se necesita una solución asistida por tecnología. Esta investigación tiene como objetivo desarrollar un sistema de puntuación basado en tecnología de sensores instalados en protectores corporales para la categoría de combate en Pencak Silat. La investigación consiste en el diseño de herramientas, pruebas de viabilidad e implementación. Los componentes del equipo instalados en el protector corporal incluyen sensores flexibles, espuma, un lector de RFID, un Arduino y NRF24L. UnS total de 9 expertos fueron asignados para evaluar su viabilidad, a saber, expertos en información y tecnología (n_1=3), expertos en instrumentos (n_2=3) y expertos en Pencak Silat (n_3=3). Luego, 120 atletas de Pencak Silat masculinos (n_1 = 70; 18.67±3.28 años) y femeninos (n_2 = 50; 18.69±3.52 años) participaron en pruebas de campo. Los datos se analizaron utilizando el índice V de Aiken, ICC, ANOVA y la prueba t de muestras independientes. Los resultados mostraron que el índice V promedio fue de 0.778; ANOVA e ICC también mostraron que no hubo diferencias en las evaluaciones entre expertos (p>0.05) con muy alta confiabilidad (p<0.05). Luego, los resultados del análisis de la prueba t de muestras independientes mostraron que no hubo diferencias significativas entre los dos sistemas de evaluación (p>0.05). En conclusión, esta herramienta puede usarse como sistema de puntuación alternativo para la categoría de combate en Pencak Silat, por lo que se espera que sea util para el jurado y los practicantes de Pencak Silat en facilitar su desempeño al proporcionar evaluaciones objetivas y transparentes.
Palabras Clave: artes marciales, protector corporal, tecnología

Fecha recepción: 30-03-24. Fecha de aceptación: 07-06-24
Nurul Ihsan
nurul_ihsan@fik.unp.ac.id

Introduction

Pencak Silat is an original martial art from Indonesia, which has been passed down from generation to generation and contains various positive values, such as moral, spiritual and social (Ihsan et al., 2022). This martial art is competed in the art and fighting categories (one on one). The art category demonstrates movements with bare hands or weapons, while the fighting category requires the fighter to have good elements of attack, defence, technique and tactics (Irawan, Nomi, & Peng, 2021). The fighter who wins the match in the fighting category is the fighter who gets more points than his opponent through every successful attack on the target (Ihsan et al., 2022; Liskustyawati, Mukholid, & Waluyo, 2019).

Currently, the scoring system for fighting categories in Pencak Silat is determined based on the jury's observations, so there is a risk of errors in decision-making. The jury is required to be extra careful in assessing a fighter's attack that hits the target, especially since fighting sports are done with swift movements and high skill (Worsey, Espinosa, Shepherd, & Thiel, 2019). The subjectivity of this assessment is also one of the problems with Pencak Silat not yet competed at the Olympics, but only until the Asian Games (Dimyati, Irianto, & Lumintuarso, 2020). Therefore, technological assistance is needed to support performance and overcome errors in data collection (Alnedral, Ihsan, Mario, Aldani, & Sari, 2023; Brown et al., 2020; Handayani, Myori, Yulifri, Komaini, & Mario, 2023), developing elite and amateur sports (Camomilla, Bergamini, Fantozzi, & Vannozzi, 2018; Matsuwaka & Latzka, 2019; Oh, Johnson, & Syrop, 2019), this also includes the use of sensors (Firdaus & Mario, 2022; Ihsan, Yulkifli, & Yohandri, 2016; Irawan et al., 2024).

The development and advancement of sensor technology has made it an ideal tool for collecting high-quality, organized and transparent data (Gao et al., 2016; Kim, Campbell, de Ávila, & Wang, 2019; Liskustyawati et al., 2019), so these are often worn into sports gear (Komaini et al., 2023; Li et al., 2015; Mendes, Vieira, Pires, & Stevan,

2024, Retos, 57, 684-691

2016). The sophistication of sensor technology in capturing and translating physical attributes (for example temperature, mass, speed, pressure or objects) can facilitate human performance in almost all aspects (Batool et al., 2019; Huỳnh et al., 2007; Javaid et al., 2021; Wang et al., 2015). A system can use many sensors with different capacities, depending on their functional complexity (Wu, Dyson, & Nazarpour, 2021; Zhang, Ang, Xiao, & Tham, 2009). The level of accuracy in analyzing human movements without different markers has not been established. However, it could be improved by adding devices that can be worn on athletes or sports objects (Leser, Baca, & Ogris, 2011). Therefore, the sports and health sectors have currently used Real-Time Location Systems (RTLS) and technology that can be used separately to solve specific problems (Boulos & Berry, 2012; Castillo, Carmona, Sánchez, & Ortega, 2018; Ho et al., 2020).

The use of sensor technology in martial arts has been investigated in previous studies, for example a study by Wang et al. (2017), who measured plantar pressure during a jump kick using a PVDF sensor insole in Wushu, to provide scientific guidance and technical support for promotion and level improvement, visual sense and competitiveness in Wushu. Ishac and Eager (2021), developed a sensing system that incorporated an ICSensor Model 3140 accelerometer mounted on a punching bag to measure dynamic acceleration. Analysis of speed, impulse, momentum and impact force of Taekwondo's sine wave punches and step-back punches were evaluated, and compared with the martial arts styles of Hapkido and Shaolin Wushu (Ishac & Eager, 2021). Then, the use of sensor technology in mixed martial arts is based on the study of Beranek et al. (2020), who considered the difference in strength between straight punches, elbow strikes and palm strikes on the ground and punches. Unfortunately, very few studies investigate the use of sensor technology for scoring systems in combat sports, especially in Pencak Silat. To our knowledge, the study Chi (2005), applied technology to assist judges in determining contact and strike force in competition. The Hogu sensor was developed as a system consisting of several piezo-electric sensors that can be used to measure impact force, but this study focuses on Taekwondo. Meanwhile in Pencak Silat, the use of sensor technology is often carried out in technical skills such as kick speed with dynamic targets (Damrah et al., 2023), and kick speed which can read action and reaction data sequentially in milliseconds (Ihsan et al., 2016).

Therefore, this research aims to develop a scoring system using sensor technology installed on body protectors for the fighting category in Pencak Silat. To the best of our knowledge, this is the first study to apply sensor technology to body protectors for the fighting category in Pencak Silat, with the hope of making it easier and improving the performance of the jury to provide objective and transparent assessments.

Materials and Methods

Participant

A total of 9 experts were involved in assessing the tool's suitability, each of whom was three information and technology experts, three instrument experts, and three Pencak Silat experts. Then, 120 Pencak Silat athletes in West Sumatra, Indonesia participated voluntarily in field trials. Recruitment of participants was based on several considerations, including participants who had participated in regional student sports events, participated voluntarily by agreeing in writing, and were willing to comply with the provisions during field trials. Participants were male (n_1=70; 18.67±3.28 years; 55.23±4.81 kg; 161.72±3.67 cm) and female (n_2=50; 18.69±3.52 years; 52.26±4.33 kg; 156.85±3.98 cm).

Procedure

The procedures in this research include tool design, feasibility testing, and implementation. Tool design is the initial stage for assembling a scoring system using sensor technology on the body protector. These components include a flex sensor, foam, RFID reader, Arduino, and NRF24L (Figures 1 and 2). The tools that have been designed are assessed by experts, and the final stage is the implementation of the tools involving fighters facing one on one (red and blue corners). The data taken is the red corner fighter, namely the conformity between the jury's assessment and the scoring system using sensor technology installed on the body protector.

The tool's working system is that the Arduino will read changes in values on the flex sensor when pressure is applied. Meanwhile, the foam functions as a pressure barrier and creates an indentation in the flex sensor. Then, the Analog to Digital Converter (ADC) reading value is obtained by converting the voltage reading on the analogue pin (microcontroller).

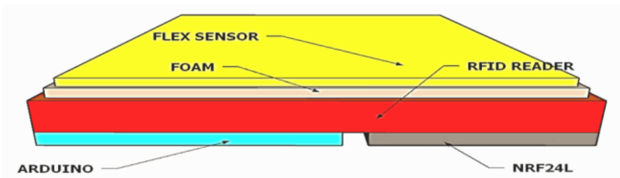

Figure 1. Design of tools for scoring system mounted on body protector

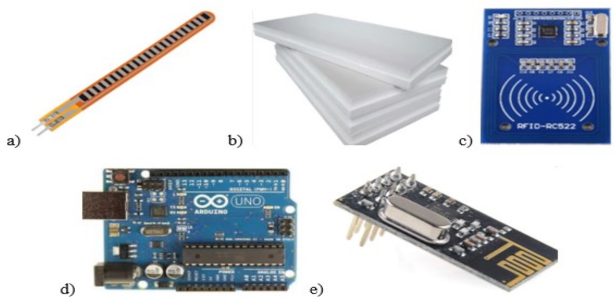

Figure 2. a) flex sensor, b) foam, c) RFID reader, d) Arduino, and e) NRF24L

Testing and collecting pressure data on the sensor was carried out using an object with a diameter of 1.5 cm. The amount of pressure read by the flex sensor is inversely proportional to the voltage on the sensor (Table 1).

In RFID reader testing, variations in the distance between the RFID reader and the RFID tag are carried out. This aims to determine the maximum limit for RFID to be read. As presented in Table 2, the maximum distance that can be read was 5 cm. Then, experiments were also carried out when the RFID reading was blocked by an object (Table 2). This experiment was carried out to determine the maximum distance that RFID can read when it is blocked by an object measuring 1 cm. This size is the average distance between the positions of the sensors installed on the body protector.

Table 1.
Pressure on the sensor

Weight (g)	ADC sensor values	Rated tension (v)	Weight (g)	ADC sensor values	Rated tension (v)
400	800	3.91	4400	400	1.95
800	760	3.71	4800	360	1.76
1200	730	3.56	5200	340	1.66
1600	680	3.32	5600	300	1.46
2000	640	3.13	6000	270	1.32
2400	600	2.93	6400	230	1.12
2800	570	2.78	6800	180	0.88
3200	550	2.69	7200	140	0.68
3600	500	2.44	7600	100	0.49
4000	460	2.25	8000	40	0.20

ADC=Vsignal/Vref*1023; Vsignals is the sensor flex voltage and Vref is the microcontroller reference voltage input.

Table 2.
Variation in distance read by RFID when blocked by the object

Distance variation*				Maximum distance of RFID when obstructed by objects			
Distance (mm)	RFID serial number	Distance (mm)	RFID serial number	Distance (mm)	RFID number	Distance (mm)	RFID number
50	1199110456	550	Cannot be read	100	1199110456	600	Cannot be read
100	1199110456	600	Cannot be read	150	1199110456	650	Cannot be read
150	1199110456	650	Cannot be read	200	1199110456	700	Cannot be read
200	1199110456	700	Cannot be read	250	1199110456	750	Cannot be read
250	1199110456	750	Cannot be read	300	1199110456	800	Cannot be read
300	1199110456	800	Cannot be read	350	1199110456	850	Cannot be read
350	1199110456	850	Cannot be read	400	Cannot be read	900	Cannot be read
400	1199110456	900	Cannot be read	450	Cannot be read	950	Cannot be read
450	1199110456	950	Cannot be read	500	Cannot be read	1000	Cannot be read
500*	1199110456	1000	Cannot be read	550	Cannot be read	1050	Cannot be read

*Maximum distance that can be read, **RFID reading when obstructed by objects.

Instruments

Expert assessments based on feasibility indicators, as presented in Table 3 are used to test the tool's feasibility.

Table 3.
Instrument feasibility tools

Information and technology expert	Instrument expert	Pencak Silat expert
Components in a series of tools	Suitability of tools with manual design	Equipment conformity with the regulations for the fighting category
Conformity of program to output	Compliance of tools with manual procedures	Suitability of equipment to the conditions for the fighting category
Completeness of the components used	Equipment compliance with the rules of the scoring system for the fighting category	Suitability of equipment to the situation for the fighting category
Security is designed components	Suitability of tools for decision making for fighting categories	The series of tools does not interfere with the fighter's comfort when fighting
	Suitability of tools with criteria in decision making for fighting categories	

The assessment categories are score 4 (very valid), score 3 (valid), score 2 (less valid), and score 1 (invalid).

Statistical analysis

Data were analyzed using IBM SPSS version 26 statistical software. V index coefficient from Aiken (Aiken, 1985), ICC (Cho, 1981) and ANOVA were used to analyze validity and reliability. Classification for validity is index $V < 0.4$ (low), $0.4 \leq V \leq 0.8$ (enough), and $V > 0.8$ (high). Meanwhile, the classification for reliability is the ICC value > 0.80 (very high), 0.61-0.80 (high), 0.41-0.60 (enough), and < 0.41 (low). Then, the independent sample t-test was also used to analyze the results of the field trials.

$$V = \frac{\sum s}{n(c-1)} \qquad ICC = \frac{\sigma_s^2}{\sigma_s^2 + \sigma_o^2 + \sigma_e^2}$$

Results

Tool validity

The results of the tool's feasibility study show that the average V index was 0.778. Each assessment is presented in Table 4 and Figure 3.

Table 4.
V index coefficient

2024, Retos, 57, 684-691

Experts (*n*=9)	Eligibility items	Raters			S_1	S_2	S_3	$\sum s$	*n(c-1)*	*V*	*M*±*SD*
		1	2	3							
Information and technology (*n*=3)	*n*=4	3	4	3	2	3	2	7	9	0.778	0.861±0.167
		4	4	4	3	3	3	9	9	1.000	
		3	3	3	2	2	2	6	9	0.667	
		4	4	4	3	3	3	9	9	1.000	
Instruments (*n*=3)	*n*=5	3	3	3	2	2	2	6	9	0.667	0.711±0.099
		3	3	3	2	2	2	6	9	0.667	
		3	3	3	2	2	2	6	9	0.667	
		3	3	3	2	2	2	6	9	0.667	
		4	3	4	3	2	3	8	9	0.889	
Pencak Silat (*n*=3)	*n*=4	3	3	3	2	2	2	6	9	0.667	0.778±0.157
		3	3	3	2	2	2	6	9	0.667	
		4	4	4	3	3	3	9	9	1.000	
		3	4	3	2	3	2	7	9	0.778	
M±*SD*											0.778±0.143

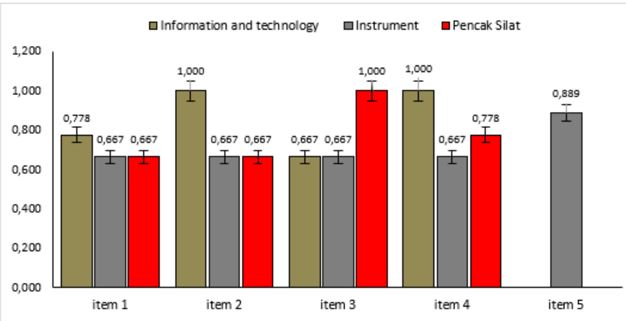

Figure 3. V index coefficient from each assessment

Tool reliability

The results of ANOVA and ICC show that there are no differences in assessments between experts (p>0.05) with very high reliability (p<0.05) (Tables 5 and 6). The average ICC value also proves this was 0.838 (Table 6).

Table 5.
ANOVA

Raters	Source		Sum of Squares	*Df*	Mean Square	*F*	*P*
Information and technology		Between people	2.250	3	0.750		
	Within people	Between items	0.167	2	0.083	1.000	0.422
		Residual	0.500	6	0.083		
		Total	0.667	8	0.083		
		Total	2.917	11	0.265		
Instruments		Between people	1.067	4	0.267		
	Within people	Between items	0.133	2	0.067	1.000	0.410
		Residual	0.533	8	0.067		
		Total	0.667	10	0.067		
		Total	1.733	14	0.124		
Pencak Silat		Between people	2.000	3	0.667		
	Within people	Between items	0.167	2	0.083	1.000	0.422
		Residual	0.500	6	0.083		
		Total	0.667	8	0.083		
		Total	2.667	11	0.242		

There were no differences in assessments between experts (p>0.05).

Table 6.
Intraclass correlation coefficient

Raters	Source	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
			Lower Bound	Upper Bound	Value	*df1*	*df2*	*P*
Information and technology	Single Measures	0.727	0.108	0.978	9.000	3	6	0.012
	Average Measures	0.889	0.267	0.992	9.000	3	6	0.012
Instruments	Single Measures	0.500	-0.075	0.921	4.000	4	8	0.045
	Average Measures	0.750	-0.263	0.972	4.000	4	8	0.045
Pencak Silat	Single Measures	0.700	0.066	0.975	8.000	3	6	0.016
	Average Measures	0.875	0.175	0.992	8.000	3	6	0.016
M ± SD		0.838 ± 0.077						

Two-way mixed effects model where people effects are random and measures effects are fixed; ICC value was significant (p<0.05).

Tool implementation

Field trial data shows that the two scoring systems have average differences for male and female fighters (Table 7).

The results of testing the analysis requirements presented in Table 8, show that the data is normally distributed and homogeneous (p>0.05).

Table 7.
Descriptive analysis

Data	Male (*n*=70)			Female (*n*=50)		
	Min	Max	*M*±*SD*	Min	Max	*M*±*SD*
Jury	3.00	22.00	13.54±3.70	5.00	16.00	12.48±2.49
Body protector with sensors installed	3.00	17.00	12.80±2.65	7.00	15.00	12.56±2.02

Table 8.
Summary of data normality and homogeneity tests

Gender	Data	Df	Normality test				Homogeneity test	
			Kolmogorov-Smirnov		Shapiro-Wilk		Levene	*P*
			Statistic	*P*	Statistic	*P*		
Male	Jury	35	0.156	0.131	0.920	0.115	1.862	0.177
	Body protector with sensors installed	35	0.163	0.119	0.886	0.102		
Female	Jury	25	0.156	0.148	0.904	0.122	0.307	0.582
	Body protector with sensors installed	25	0.202	0.110	0.897	0.116		

Normal and homogeneous (p>0.05).

Then, the results of the independent sample t-test analysis showed no significant difference between the two assessment systems (jury and body protector worn by sensors) (p>0.05) (Table 9).

Table 9.
Analysis of the differences between the two assessment systems

Gender	Data	Df	t-test for equality of means			95%	
			P (2-tailed)	MD	SED	Lower	Upper
Male	Equal variances assumed	68	0.338	0.743	0.769	-0.792	2.278
	Equal variances not assumed	61.698	0.338	0.743	0.769	-0.795	2.281
Female	Equal variances assumed	48	0.901	-0.080	0.641	-1.368	1.208
	Equal variances not assumed	46.096	0.901	-0.080	0.641	-1.370	1.210

Significant (p<0.05).

Discussion

This research aims to develop a scoring system using sensor technology mounted on body protectors for the Pencak Silat fighting category. The results show that this scoring system can be used as a solution for jury to provide objective and transparent assessments. This tool has been assessed by experts before field trials, as evidenced by the V index, ICC and ANOVA values. Meanwhile, the implementation involves fighters facing one-on-one (red and blue corners), and the data taken is from the red corner fighter, namely the conformity between the jury's assessment and the scoring system using sensor technology installed on the body protector. This finding aligns with a study by Chi (2005), that applied sensor technology to assist judges in determining contact and strike force in Taekwondo. The results report that the Hogu Sensor developed can be used to measure impact force.

Combat sports generally involve fast movements, so sensor technology is ideal for measuring such actions (Worsey et al., 2019). From this movement, the acceleration and rotation of the device can be measured, recorded and transmitted from the body (Espinosa, Lee, & James, 2015; Worsey, Pahl, Thiel, & Milburn, 2018). Therefore, it is not surprising that researchers make it the main focus of their research, including martial arts (Beranek et al., 2020; Chi, 2005; Ishac & Eager, 2021; Usra et al., 2024; Wang et al., 2017; Worsey et al., 2019). A study Ihsan et al. (2016), reported that sensor-based kick speed measurements in Pencak Silat can collect action and reaction speed data sequentially in milliseconds, with action and reaction speed accuracy of 99.29% and 99.33%. A study Damrah et al. (2023), also reported that a sensor-based kick speed measurement tool could be used easily, practically and accurately in collecting kick data in Pencak Silat. The components used to design this measuring instrument are sensors, software and digital readings on the LCD screen. Other components are Arduino Uno, 20 x 4 LCD, MPU 6050 sensor, HC05 Bluetooth module, condenser mic module microsensor, and patching pad (Damrah et al., 2023). Apart from involving technological assistance in sports performance, programmed training programs are also essential to get optimal results (Firdaus et al., 2023; Umar, Alnedral, Ihsan, Mario, & Mardesia, 2023; Welis et al., 2024; Welis, Yendrizal, Darni, & Mario, 2023).

The sensor in the developed tool is mounted on a body protector consisting of a flex sensor, foam, RFID reader, Arduino, and NRF24L components. Testing and collecting pressure data on the sensor was carried out using an object with a diameter of 1.5 cm. The amount of pressure read by the flex sensor is inversely proportional to the voltage on the sensor. In testing the RFID reader, variations in the distance between the RFID reader and the RFID tag were carried out, and the maximum distance that could be read was 5 cm. Experiments were also carried out to determine the maximum distance that RFID can read when it is blocked by an object measuring 1 cm. Apart from that, this tool is designed to not interfere with the comfort and safety of fighters when competing. This is to the opinion of Worsey et al. (2019), that in combat sports there are obstacles related to electronic systems that must withstand high impact acceleration, environmental impacts of temperature and humidity, wireless connectivity problems due to rotation of body movements, the shape and placement of sensors must be such that so that a direct impact on the sensor will not injure the participant and will not damage the operational characteristics of the device (Worsey et al., 2019).

The scoring system using sensor technology mounted on a body protector has undergone the feasibility and implementation testing stages. Content validity involves nine experts, who are independently tasked with assessing and evaluating the relevance of the content represented in the form of tools or instruments (Wynd, Schmidt, & Schaefer, 2003). According to Almanasreh et al. (2019), content validity is the minimum requirement for all instruments developed. This differs from other types of validity, in that it describes what is required of the instrument content, and is not related to the scores obtained from the construct (Sireci & Faulkner-Bond, 2014; Yaakop, Koh, & Yasin, 2023). In this regard, the construct underlying a test or instrument must be conceptualized and have clear evidence regarding its operational components (Polit, Beck, & Owen, 2007). Reliability also shows the consistency between the assessments given (Rifki et al., 2022; Robertson, Burnett, & Cochrane, 2013), where ICC is used to analyze the level of agreement between several raters (Koo & Li, 2016). Experts discussed these results until an agreement was reached for field trials.

Based on data obtained during the tool development to implementation stages, we realize several limitations must be reported. This tool only focuses on martial arts for the fighting category in Pencak Silat. The field trials involved 120 student-level Pencak Silat athletes, so elite athletes are needed to perfect it. The tool has yet to be implemented in official competitions. These limitations need to be validated for future research, so that the tool can be used in official competitions.

Conclusions

The conclusion from these findings is the creation of a tool in the form of a scoring system using sensor technology installed on body protectors for the fighting category in Pencak Silat. This tool has been assessed by experts before field trials, as evidenced by the V index, ICC and ANOVA values. Implementation involves fighters facing one on one (red and blue corners), and the data taken is from the red corner fighter, namely the conformity between the jury's assessment and the scoring system using sensor technology installed on the body protector. This tool is designed with various components a flex sensor, foam, an RFID reader, an Arduino, and NRF24L. Arduino will read the change in value on the flex sensor when pressure is applied, while the foam functions as a pressure barrier and creates an indentation on the flex sensor. Then, the ADC reading value is obtained by converting the voltage reading on the analogue pin (microcontroller). Testing and collecting pressure data on the sensor was carried out using an object with a diameter of 1.5 cm. The amount of pressure read by the flex sensor is inversely proportional to the voltage on the sensor. In testing the RFID reader, variations in the distance between the RFID reader and the RFID tag were carried out, and the maximum distance that could be read was 5 cm. Experiments were also carried out to determine the maximum distance that RFID can read when it is blocked by an object measuring 1 cm. Finally, it is hoped that this tool will be helpful for jury and Pencak Silat practitioners in faciliting their performance in providing objective and transparent assessments. Future research must involve elite martial artists by implementing it in official competitions.

Conflicts of interest

The authors report no potential conflict of interest.

References

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, *45*(1), 131–142.

Almanasreh, E., Moles, R., & Chen, T. F. (2019). Evaluation of methods used for estimating content validity. *Research in Social and Administrative Pharmacy*, *15*(2), 214–221. https://doi.org/10.1016/j.sapharm.2018.03.066

Alnedral, Ihsan, N., Mario, D. T., Aldani, N., & Sari, D. P. (2023). Digital-based e-modules in Tarung Derajat martial arts learning at basic level. *International Journal of Human Movement and Sports Sciences*, *11*(2), 306–315. https://doi.org/10.13189/saj.2023.110207

Batool, M., Jalal, A., & Kim, K. (2019). Sensors technologies for human activity analysis based on SVM optimized by PSO algorithm. *2019 International Conference on Applied and Engineering Mathematics, ICAEM 2019 - Proceedings*, 145–150. https://doi.org/10.1109/ICAEM.2019.8853770

Beranek, V., Stastny, P., Novacek, V., Votapek, P., & Formanek, J. (2020). Upper limb strikes reactive forces in mix martial art athletes during ground and pound tactics. *International Journal of Environmental Research and Public Health*, *17*(21), 1–15. https://doi.org/10.3390/ijerph17217782

Boulos, M. N. K., & Berry, G. (2012). Real-time locating systems (RTLS) in healthcare: A condensed primer. *International Journal of Health Geographics*, *11*(25), 1–8. https://doi.org/10.1186/1476-072X-11-25

Brown, K., Toombs, M., Nasir, B., Kisely, S., Ranmuthugala, G., Brennan-Olsen, S. L., … Hides, L. (2020). How can mobile applications support suicide prevention gatekeepers in Australian Indigenous communities? *Social Science and Medicine*, *258*(May), 113015. https://doi.org/10.1016/j.socscimed.2020.113015

Camomilla, V., Bergamini, E., Fantozzi, S., & Vannozzi, G. (2018). Trends supporting the in-field use of wearable inertial sensors for sport performance evaluation: A systematic review. *Sensors*, *18*(3), 1–50. https://doi.org/10.3390/s18030873

Castillo, A. B., Carmona, C. D. G., Sánchez, E. D. la cruz, & Ortega, J. P. (2018). Accuracy, intra- and inter-unit reliability, and comparison between GPS and UWB-based position-tracking systems used for time–motion analyses in soccer. *European Journal of Sport Science*, *18*(4), 450–457. https://doi.org/10.1080/17461391.2018.1427796

Chi, E. H. (2005). Introducing wearable force sensors in martial arts. *IEEE Pervasive Computing*, *4*(3), 47–53. https://doi.org/10.1109/MPRV.2005.67

Cho, D. W. (1981). Inter-rater reliability: Intraclass correlation coefficients. *Educational and Psychological Measurement, 41*(1), 223–226.

Damrah, D., Ihsan, N., Muharel, A., Komaini, A., Rifki, M. S., Sepriadi, S., & Ilham, I. (2023). A measuring tool for kick speed with dynamic targets: A digital-based instrument designed for Pencak Silat learning. *Annals of Applied Sport Science*, *11*(4). http://aassjournal.com/article-1-1216-en.html

Dimyati, Irianto, D. P., & Lumintuarso, R. (2020). Exploring the psychological skills of Indonesian Pencak Silat Athletes at the 18th Asian games. *Ido Movement for Culture*, *20*(2), 10–16. https://doi.org/10.14589/ido.20.2.2

Espinosa, H. G., Lee, J., & James, D. A. (2015). The inertial sensor: A base platform for wider adoption in sports science applications. *Journal of Fitness Research*, *4*(1), 13–20.

Firdaus, K., Hartoto, S., Hariyanto, A., Subagya, I., Nikmatullaili, Mario, D. T., & Zulbahri. (2023). Evaluation of several factors that affect the learning outcomes of Physical Education. *International Journal of Human Movement and Sports Sciences*, *11*(1), 27–36. https://doi.org/10.13189/saj.2023.110104

Firdaus, K., & Mario, D. T. (2022). Development of service sensor tools on table tennis net. *Journal of Physical Education and Sport*, *22*(6), 1449–1456. https://doi.org/10.7752/jpes.2022.06182

Gao, W., Emaminejad, S., Nyein, H. Y. Y., Challa, S., Chen, K., Peck, A., … Javey, A. (2016). Fully integrated wearable sensor arrays for multiplexed in situ perspiration analysis. *Nature*, *529*(7587), 509–514. https://doi.org/10.1038/nature16521

Handayani, S. G., Myori, D. E., Yulifri, Komaini, A., & Mario, D. T. (2023). Android-based gymnastics learning media to improve handstand skills in junior high school students. *Journal of Human Sport and Exercise*, *18*(3), 690–700. https://doi.org/10.14198/jhse.2023.183.15

Ho, H. J., Zhang, Z. X., Huang, Z., Aung, A. H., Lim, W.-Y., & Chow, A. (2020). Use of a real-time locating system for contact tracing of health care workers during the COVID-19 pandemic at an infectious disease center in Singapore: Validation study. *Journal of Medical Internet Research*, *22*(5), e19437. https://doi.org/10.2196/19437

Huỳnh, T., Blanke, U., & Schiele, B. (2007). Scalable recognition of daily activities with wearable sensors. *Int. Symp. Locat. Context*, 50–67. https://doi.org/10.1007/978-3-540-75160-1_4

Ihsan, N., Hanafi, R., Sepriadi, Okilanda, A., Suwirman, & Mario, D. T. (2022). The effect of limb muscle explosive power, flexibility, and achievement motivation on sickle kick performance in Pencak Silat learning. *Physical Education Theory and Methodology*, *22*(3), 393–400. https://doi.org/10.17309/tmfv.2022.3.14

Ihsan, N., Yulkifli, & Yohandri. (2016). Development of speed measurement system for Pencak Silat kick based on sensor technology. *Journal of Physics: Conference Series*, *755*(1), 1–8. https://doi.org/10.1088/1742-6596/755/1/011001

Irawan, F. A., Nomi, M. T., & Peng, H.-T. (2021). Pencak Silat side kick in persinas ASAD: Biomechanics analysis. *International Journal of Human Movement and Sports Sciences*, *9*(6), 1230–1235. https://doi.org/10.13189/saj.2021.090617

Irawan, R., Yenes, R., Mario, D. T., Komaini, A., Orhan, B. E., & Ayubi, N. (2024). Design of a sensor technology-based hand-eye coordination measuring tool: Validity and reliability. *Ret*, *2041*, 966–973. https://doi.org/10.47197/retos.v56.103610

Ishac, K., & Eager, D. (2021). Evaluating martial arts punching kinematics using a vision and inertial sensing system. *Sensors*, *21*(6), 1–25. https://doi.org/10.3390/s21061948

Javaid, M., Haleem, A., Rab, S., Singh, R. P., & Suman, R. (2021). Sensors for daily life: A review. *Sensors International*, *2*(7), 100121. https://doi.org/10.1016/j.sintl.2021.100121

Kim, J., Campbell, A. S., de Ávila, B. E. F., & Wang, J. (2019). Wearable biosensors for healthcare monitoring. *Nature Biotechnology*, *37*(4), 389–406. https://doi.org/10.1038/s41587-019-0045-y

Komaini, A., Kiram, Y., Gusril, G., Mario, D. T., Handayani, S. G., & Erianjoni, E. (2023). Fundamental movement skills in children in Mentawai Islands: Indigenous tribes in Indonesia. *Physical Education Theory and Methodology*, *23*(4), 520–530. https://doi.org/10.17309/tmfv.2023.4.05Koo, T. K., & Li, M. Y. (2016). A Guideline of selecting and reporting Intraclass Correlation Coefficients for reliability research. *Journal of Chiropractic Medicine*, *15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Leser, R., Baca, A., & Ogris, G. (2011). Local positioning systems in (game) sports. *Sensors*, *11*(10), 9778–9797. https://doi.org/10.3390/s111009778

Li, R. T., Kling, S. R., Salata, M. J., Cupp, S. A., Sheehan, J., & Voos, J. E. (2015). Wearable performance devices in sports medicine. *Sports Health*, *8*(1), 74–78. https://doi.org/10.1177/1941738115616917

Liskustyawati, H., Mukholid, A., & Waluyo, W. (2019). The average needs of Pencak Silat basic technique from sparring category. *International Journal of Multicultural and Multireligious Understanding*, *6*(4), 308–313. https://doi.org/10.18415/ijmmu.v6i4.972

Matsuwaka, S. T., & Latzka, E. W. (2019). Summer adaptive sports technology, equipment, and injuries. *Sports Medicine and Arthroscopy Review*, *27*(2), 48–55. https://doi.org/10.1097/JSA.0000000000000231

Mendes, J. J. A., Vieira, M. E. M., Pires, M. B., & Stevan, S. L. (2016). Sensor fusion and smart sensor in sports and biomedical applications. *Sensors*, *16*(10), 1–31. https://doi.org/10.3390/s16101569

Oh, H., Johnson, W., & Syrop, I. P. (2019). Winter adaptive sports participation, injuries, and equipment. *Sports Medicine and Arthroscopy Review*, *27*(2), 56–59. https://doi.org/10.1097/JSA.0000000000000236

Polit, D. F., Beck, C. T., & Owen, S. V. (2007). Focus on research methods: Is the CVI an acceptable indicator of content validity ? Appraisal and recommendations. *ResearchinNursing&Health*, *30*(4), 459–467. https://doi.org/10.1002/nur.20199

Rifki, M. S., Hanifah, R., Sepdanius, E., Komaini, A., Ilham, Fajri, H. P., & Mario, D. T. (2022). Development of a volleyball test instrument model. *International Journal of Human Movement and Sports Sciences*, *10*(4), 807–814. https://doi.org/10.13189/saj.2022.100421

Robertson, S. J., Burnett, A. F., & Cochrane, J. (2013). Tests examining skill outcomes in sport: A systematic review of measurement properties and feasibility. *Sports Medicine*, *44*(4), 501–518. https://doi.org/10.1007/s40279-013-0131-0

Sireci, S. G., & Faulkner-Bond, M. (2014). *Validity evidence based on test content*. Psicothema.

Umar, U., Alnedral, A., Ihsan, N., Mario, D. T., & Mardesia, P. (2023). The effect of learning methods and motor skills on the learning outcomes of basic techniques in volleyball. *Journal of Physical Education and Sport*, *23*(9), 2453–2460. https://doi.org/10.7752/jpes.2023.09282

Usra, M., Lesmana, I. B., Octara, K., Bayu, W. I., Badau, A., Ishak, A., & Setiawan, E. (2024). Augmented reality training on combat sport: Improving the quality of physical fitness and technical performance of young athletes. *Retos*, *54*, 835–843. https://doi.org/10.47197/retos.v54.103743

Wang, X., Zhi, C., & Wang, Q. (2017). Research on Wushu actions and techniques based on a biomechanical sensor system. *International Journal Bioautomation*, *21*(2), 199–206.

Wang, Z. L., Chen, J., & Lin, L. (2015). Progress in triboelectric nanogenertors as new energy technology and self-powered sensors. *Energy and Environmental Science*, *8*(8), 2250–2282. https://doi.org/10.1039/c5ee01532d

Welis, W., Effendi, R., Ilham, I., Mario, D. T., Bafirman, B., & Ihsan, N. (2024). Protein-based soy flour supplementation to support the effects of weight training on muscle hypertrophy. *Retos*, *51*(1), 923–929. https://doi.org/10.47197/retos.v51.99162

Welis, W., Yendrizal, Darni, & Mario, D. T. (2023). Physical fitness of students in Indonesian during the COVID-19 period: Physical activity, body mass index, and socioeconomic status. *Physical Activity Review*, *11*(1), 77–87. https://doi.org/10.16926/par.2023.11.10

Worsey, M. T. O., Espinosa, H. G., Shepherd, J. B., & Thiel, D. V. (2019). Inertial sensors for performance analysis in combat sports: A systematic review. *Sports*, 7(28), 1–19. https://doi.org/10.3390/sports7010028

Worsey, M. T. O., Pahl, R., Thiel, D. V., & Milburn, P. D. (2018). A comparison of computational methods to determine intrastroke velocity in swimming using IMUs. *IEEE Sensors Letters*, *2*(1), 1–4. https://doi.org/10.1109/LSENS.2018.2804893

Wu, H., Dyson, M., & Nazarpour, K. (2021). Arduino-based myoelectric control: Towards longitudinal study of prosthesis use. *Sensors*, *21*(3), 1–13. https://doi.org/10.3390/s21030763

Wynd, C. A., Schmidt, B., & Schaefer, M. A. (2003). Two quantitative approaches for estimating content validity. *Western Journal of Nursing Research*, *25*(5), 508–518. https://doi.org/10.1177/0193945903252998

Yaakop, N., Koh, D., & Yasin, M. (2023). A content validation of focus group discussions based on need analysis in a physical education training module for primary school teachers. *Retos*, *50*, 1115–1122. https://doi.org/10.47197/retos.v50.100191

Zhang, S., Ang, M. H., Xiao, W., & Tham, C. K. (2009). Detection of activities by wireless sensors for daily life surveillance: Eating and drinking. *Sensors*, *9*(3), 1499–1517. https://doi.org/10.3390/s90301499

Datos de los/as autores/as:

Nurul Ihsan	nurul_ihsan@fik.unp.ac.id	Autor/a
Yulkifli	yulkifli@fmipa.unp.ac.id	Autor/a
Ahmaddul Hadi	dulhadi@ft.unp.ac.id	Autor/a
Yohandri	yohandri@fmipa.unp.ac.id	Autor/a
Deby Tri Mario	debytrimario@unp.ac.id	Autor/a
Novadri Ayubi	novadriayubi@unesa.ac.id	Autor/a
Aydin Karacam	akaracam@bandirma.edu.tr	Autor/a
Zsolt Németh	zsolt.nemeth@gamma.ttk.pte.hu	Autor/a
Bekir Erhan Orhan	bekirerhanorhan@aydin.edu.tr	Autor/a
Bekir Erhan Orhan	bekirerhanorhan@aydin.edu.tr	Traductor/a