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Test-retest reliability and construct validity of Inosen's Silat Momentum Test
Fiabilidad test-retest y validez de constructo del test Silat Momentum de Inosen

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Abstract. Problem Statements: The kick in Pencak Silat has a magnitude called momentum, which requires a tool capable of measuring several variables based on the International System of Units (SI) in real-time. Nowadays, there are affordable and reliable sensor technologies to meet these needs. Purpose: The research aimed to design a test instrument that utilizes sensor technology to measure kick momentum in the sparring category of Pencak Silat following the applicable SI, and to test its reliability and validity. The resulting instrument is named Inosen's Silat Momentum Test. Approach: This study followed Johnson and Nelson's seven-test construction process. Twenty-four Pencak Silat athletes, consisting of 12 elite and 12 non-elite participants, were involved in the evaluation process. The test's reliability was assessed by examining the correlation between the test and retest results. The construct validity test was conducted by comparing the results of the front kick tests of elite and non-elite Pencak Silat athletes. Data analysis was performed using Pearson correlation and independent t-tests using Minitab 21.4.1 software. Results: The results of the test and retest indicate a very high correlation ($r = 0.923$), demonstrating the consistent ability of Inosen's Silat Momentum Test to measure kick momentum. The study found a statistically significant difference in the Inosen's Silat Momentum Test scores ($p < 0.05$) between the elite fighter group (average score of 463.3 kg.m/s) and the non-elite fighter group (average score of 375 kg.m/s). The results indicate that Inosen's Silat Momentum Test is an effective instrument for differentiating kick momentum based on fighter performance. Conclusions: Based on the findings, it is inferred that Inosen's Silat Momentum Test is a reliable and valid instrument for measuring Pencak Silat kick momentum according to SI standards.
Keywords: biomechanics, kick momentum, pencak silat, performance test, sensor technology.

Resumen. Planteamiento del problema: La patada en Pencak Silat tiene una magnitud denominada impulso, que requiere de una herramienta capaz de medir diversas variables basadas en el Sistema Internacional de Unidades (SI) en tiempo real. En la actualidad, existen tecnologías de sensores asequibles y fiables para satisfacer estas necesidades. Propósito: El objetivo de la investigación fue diseñar un instrumento de prueba que utilice tecnología de sensores para medir el impulso de la patada en la categoría de sparring de Pencak Silat siguiendo el SI aplicable, y probar su fiabilidad y validez. El instrumento resultante se denomina Inosen's Silat Momentum Test. Planteamiento: Este estudio sigue el proceso de construcción de siete tests de Johnson y Nelson. Veinticuatro atletas de Pencak Silat, 12 de élite y 12 de no élite, participaron en el proceso de evaluación. La fiabilidad del test se evaluó examinando la correlación entre los resultados del test y del re-test. La prueba de validez de constructo se realizó comparando los resultados de las pruebas de patada frontal de atletas de Pencak Silat de élite y de no élite. El análisis de los datos se realizó mediante la correlación de Pearson y pruebas t independientes con el software Minitab 21.4.1. Resultados: Los resultados de la prueba y el re-test indican una correlación muy alta ($r = 0,923$), lo que demuestra la capacidad consistente de la Prueba de Momento Silat de Inosen para medir el impulso de la patada. El estudio encontró una diferencia estadísticamente significativa en las puntuaciones del Inosen's Silat Momentum Test ($p < 0,05$) entre el grupo de luchadores de élite (puntuación media de 463,3 kg.m/s) y el grupo de luchadores de no élite (puntuación media de 375 kg.m/s). Los resultados indican que el Inosen's Silat Momentum Test es un instrumento eficaz para diferenciar el impulso de la patada en función del rendimiento del luchador. Conclusiones: En base a los resultados, se infiere que el Inosen's Silat Momentum Test es un instrumento fiable y válido para medir el impulso de la patada de Pencak Silat según los estándares del SI.
Palabras clave: biomecánica, impulso de patada, pencak silat, prueba de rendimiento, tecnología de sensores.

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Introduction

Pencak Silat is a unique martial art that has two categories of competition, the artistic category and the sparring category. As a martial art that is indigenous to Indonesia, the deep-rooted traditions and Pencak Silat principles are fully displayed both in the artistic and sparring categories (Yuki et al., 2023). Sparring category in Pencak Silat is one of the hardstyle/striking styles of martial arts sports that uses kicks, punches, blocks, and falls (PERSILAT, 2015). Pencak Silat in the sparring category is a full-body contact sport that involves all physical components such as endurance, strength, speed, power, stamina, strength endurance, flexibility, agility, and coordination (Syaifullah & Doewes, 2020). The sparring category of Pencak Silat has a strong and fast fighting style and intermittent fighting characteristics (Subekti et al., 2021; Suwirman et al., 2021). An athlete needs to attack using their arms or legs in a direct and powerful way without any interference to earn points in the Pencak Silat Sparring category (PERSILAT, 2015). Hence, to meet the need of physical needs and fighting characteristics, each athlete must have good momentum to ensure that their attacks will successfully hit the opponent without being blocked, parried, or caught, which can be counterattacked by the opponent. Momentum represents how much motion a moving object has. Momentum is a vector quantity that has both magnitude and direction (Kızılcık, 2021). It is also a measure of the energy contained in an object due to its motion. Momentum is always present in every collision. It also measures the amount of energy that can be transferred to another object (Merk & Resnick, 2021). In Pencak Silat, momentum plays a crucial role in generating points (Doewes et al., 2022). Additionally, records show that

most of the points in Pencak Silat are generated from kicks (44%) and punches (33%) (Nugroho, 2020). Therefore, considering the importance of momentum and the contributions of kicks in generating points in Pencak Silat, this study focuses on developing a kick-testing instrument that specifically tests and measures the momentum of kicks in Pencak Silat.

Sports science is the scientific study of the factors that influence human performance and ability. It is important to use terminology that complies with the International System of Units (SI) to ensure simplicity, precision, and accuracy. The SI system consists of seven basic units and various derived units. This system enables scientists from different fields to effectively communicate while conducting sports science research (Rodgers & Cavanagh, 1984). For sports science to progress, it must adhere to the principles and practices of science. Performance descriptions should accurately use fundamental scientific terminology, nomenclature, and units. Therefore, the appropriate unit of measurement for Pencak Silat athlete's kick momentum according to the SI is kilograms meters/seconds (kg m/s) (BIPM, 2019).

Appropriate test and measurement instruments are necessary to understand and evaluate the momentum in the Pencak Silat kick. The use of suitable tools like sensor technology can provide objective and measurable data on kick momentum (Taborri et al., 2020). This data can be used for evaluation, technique improvement, and development of training programs. Currently, there is no specific instrument for testing and measuring kick momentum in Pencak Silat. This study aims to design a reliable and valid instrument to measure kick momentum in real time according to the SI. The instrument development is expected to significantly contribute to athlete training, improve kick performance, and enhance scientific understanding of kinetic aspects in Pencak Silat.

Methods

Participants

This study involved 24 Pencak Silat athletes; 12 from the elite group and 12 from the non-elite group. The elite group consists of Central Java Province Pencak Silat athletes who have competed in the Indonesia National Student Sports Week 2023 (POMNAS 2023) in South Kalimantan, while the non-elite group consists of Sebelas Maret University Pencak Silat athletes who have never competed in tiered championships.

Procedure

Johnson & Nelson's (1986) test construction method was employed to design Inosen's Silat Momentum Test. Test construction is made when an existing test is unsuitable, inaccurate, or even non-existent in testing a required variable. Test construction aims to design new products and procedures that are systematically field-tested, evaluated, and refined until they meet certain criteria of effectiveness, quality, or similar standards. According to Johnson and Nelson (1986), the test construction steps are (1) Factor Analysis, (2) Test Items Selection and Construction, (3) Establish the Exact Procedures, (4) Reliability Test, (5) Compute the Objectivity, (6) Validation Test, and (7) Finalize the Exact Procedures.

Factor Analysis

Factor analysis was part of the preliminary study in research and development. The two main steps applied are literature study and unstructured interviews. The literature study was carried out by reviewing various literature in the form of articles and books related to product development. In the literature study, the search for articles related to product development was carried out using the Google Scholar, Mendeley, and Scopus search engines. An unstructured interview was a free discussion that discussed the need for equipment to be developed with a Pencak Silat expert from the Faculty of Sports, Sebelas Maret University, namely Dr. Haris Nugroho, S.Pd., M.Or., and a Mechatronics expert from the Faculty of Engineering, Sebelas Maret University, namely Prof. Dody Ariawan, S.T., M.T., Ph.D.

Test Items Selection and Construction

After discussing with some experts (factor analysis), the test selection and construction stage are conducted after the factor analysis. The proposed testing equipment is designed with a professional's assistance to obtain valid and reliable equipment to measure the momentum of kicks in the Pencak Silat sparring category. Based on the description, analysis, and factual findings, the following steps for the selection and construction of testing instruments were determined: (1) formulate a construction plan that includes identifying the main components to be used, including the concept of how the testing equipment will work, equipment design, and supporting electronic components as a measuring instrument. Both the measuring equipment and the supporting electronic components are combined to create a prototype and its implementation procedure.

Establish the Exact Procedures

The appropriate procedure for test administration and scoring includes several important stages. The first stage is to conduct an in-depth analysis of the purpose of Inosen's Silat Momentum Test to identify the key parameters to be measured. The measured parameters include distance, force, acceleration, mass, speed, or a combination of these variables, as well as other relevant technical aspects.

After all the parameters are identified, the subsequent step is to design a test scenario that encompasses a range of movements and kick intensities that accurately reflect those of a Pencak Silat match. The use of sensor technology enables real-time and objective data measurement; therefore, it is imperative to ensure that the sensor media is correctly installed according to its position.

After following these steps comprehensively, we produced precise and accurate procedures for administering and assessing the Inosen's Silat Momentum Test.

Reliability Test

The reliability test is conducted with the assistance of 24 Pencak Silat athletes (12 elite, 12 non-elite). The reliability coefficient is determined using the test-retest method.

Compute the Objectivity

The results of the test are not influenced by the skills or integrity of the examiner or test user, as the tool operates automatically and follows established scoring procedures consistently. Objectivity is achieved through this automated process, which eliminates the possibility of tester bias.

Validation Test

The validation test is conducted with the assistance of 24 athletes (12 elite, 12 non-elite). The validity is tested using the construct validity method. The construct validity is logical and empirical evidence to support the congruence between the tool and the kick momentum; that the tool indeed measures the momentum as dictated by the existing theories (Ary et al., 2019). The construct validity was tested by comparing the measurement results between the elite and non-elite Pencak Silat athletes.

Finalize the Exact Procedures

After completing the validation process, the next step is to finalize the test based on the validity test results. The purpose of this finalization is to ensure that the instrument or test meets the expected validity and reliability standards.

Inosen's Momentum Silat Test Design

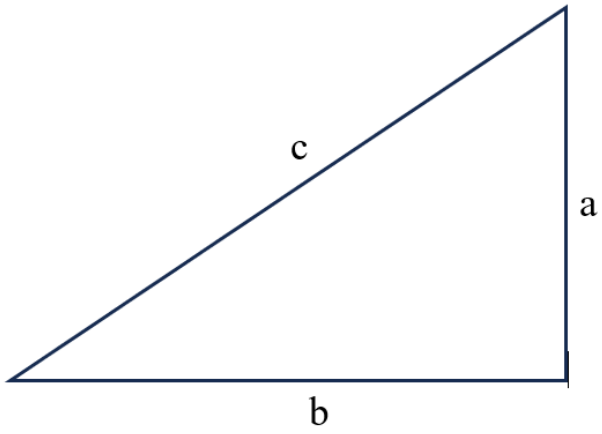
The product is developed using several main components, including Arduino NANO, laptop, mini-LCD, ultrasonic sensor, proximity sensor, spring, and punching bag. To calculate momentum ($p = m \,.\, v$), we need the data on mass (kg) and velocity (m/s).

Measuring Velocity

The velocity equation is $v = s/t$, s is distance (meters), and t is time (seconds). Thus, the SI unit for speed is measured at meters per second (m/s). To measure the distance value using the Pythagorean theorem, as shown in Figure 1, is conducted with the help of two installed ultrasonic sensors as shown in Figure 2.

Ultrasonic sensor 1 is used to measure the length of side b, while the length of side 'a' is obtained through three measurements, namely, (1) the 'a1' is the height of the stands that are already known (constant), (2) 'a2' is the distance between the top point of the stands and the bottom point of the target, automatically measured using an ultrasonic sensor 2, and (3) the 'a3' is the length of the bottom point of the target to the center point of the target that is already known (constant). The lengths of 'a1' through 'a3' are then summed and assumed to be the length of the side 'a'. Thus, the distance between the foot and the target (s) will be known through measuring side 'c' using the Pythagorean theorem.

Then, measuring time is done using a PIR motion sensor mounted around the kicker's foot that will trigger the stopwatch to start the time when the foot starts kicking. After the foot hits the target, the stopwatch will automatically stop, which is triggered by the change in spring length that occurs.



$$c^2 = a^2 + b^2$$

$$c = \sqrt{a^2 + b^2}$$

Figure 1. Pythagorean theorem and how to calculate it (Danesi, 2020).

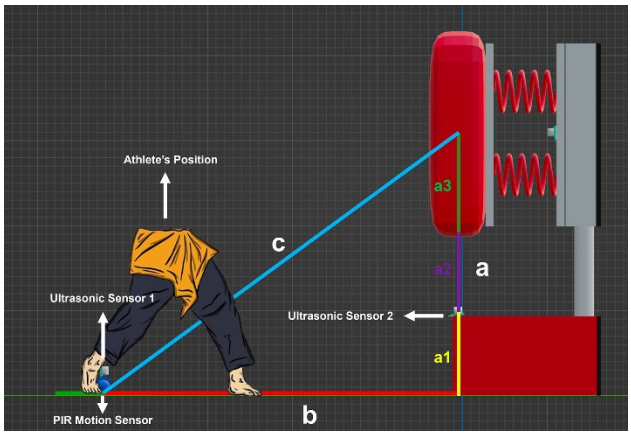


Figure 2. Construction of ultrasonic sensor and PIR motion sensor

Measuring Mass

This design applied a spring to calculate force based on Hooke's Law. The amount of force that causes the spring to move, measured in Newtons, is represented by $F = k \,.\, \Delta x$. The spring's constant, also known as the elasticity constant, is represented by k and is measured in Newtons per meter or N/m. The change in length or displacement from the initial position of the spring is represented by Δx and is measured in meters.

To find out the spring's constant, a simple spring constant test is carried out according to Figure 3, the spring is

hung and given a known amount of force and then calculated using the Hooke's Law equation above to find out the value of the spring constant (Giancoli, 2016).

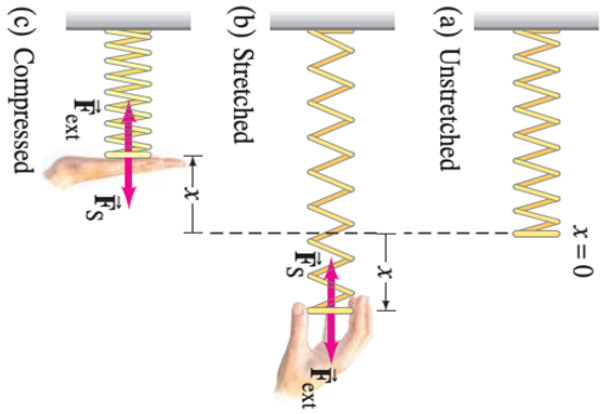


Figure 3. Simple spring constant test (Giancoli, 2016)

This design uses 4 springs arranged in parallel. As shown in Figure 4, the result of the spring constant is summed up to be $k_{eq} = k_1 + k_2 + k_3 + k_4$ (Rothbart & Brown, 2006). The total spring constant (k_{eq}) of the spring used is 15,385 N/m.

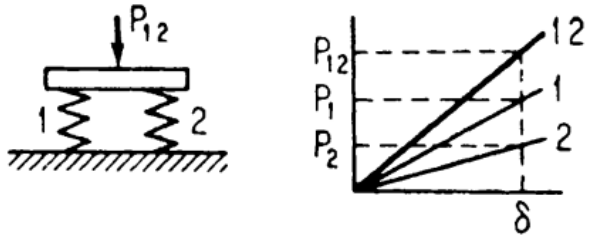


Figure 4. Parallel Springs (Rothbart & Brown, 2006)

The Δx value was measured using an ultrasonic sensor as shown in Figure 5 to see the change in the length of the spring.

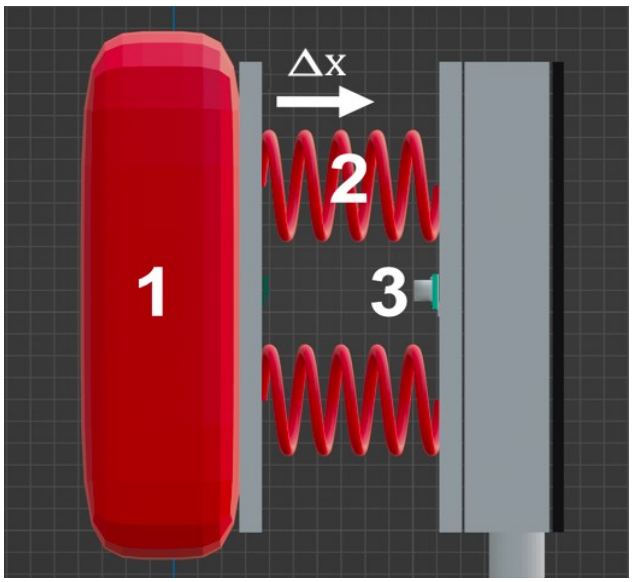


Figure 5. Construction of punching bag, springs, and ultrasonic sensor

Description:
1 = punching bag
2 = springs
3 = ultrasonic sensor
Δx = change in spring length

After getting the F value, then measure the average acceleration of the athlete's kick. The average acceleration equation is:

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1}$$

Description:
$\bar{a}$ = average acceleration (m/s^2)
v_1 = initial kick speed (m/s)
v_2 = final kick speed (m/s)
t_1 = initial kick time (s)
t_2 = final kick time (s)

After the average acceleration value is obtained then the following equation is applied to find out the mass value.

1) $F = k.\Delta x = m\bar{a}$
2) $m = \frac{F}{a} = kx/\bar{a}$

Description:
F = force (N)
k = spring constant (N/m)
Δx = change in spring length (m)
m = mass (Kg)
$\bar{a}$ = average acceleration (m/s)

By using the concept above, the mass value (m) is obtained. By obtaining the mass (Kg) and speed (m/s), the next step multiplies the two values so that the result of momentum is obtained in units of kg.m/s. All measurements are made automatically and integrated using Arduino NANO which then displays the results on a mini-LCD. The Inosen's Silat Momentum Test final design is shown in Figure 6.

Figure 6. Inosen's Silat Momentum Test final design

Statistical analysis

The data obtained in this research were analyzed using a descriptive statistical analysis. Data normality was tested using Ryan-Joiner (RJ) for each reliability and validity test data. To test reliability, Pearson correlation is applied to test and retest results to measure the extent to which different individuals' scores remain consistent. Correlation value = 0.00 means there is no relationship, a value that falls between ± 0.01 – 0.20 means there is a low relationship, ± 0.21 – 0.50 means there is a low to moderate relationship, ± 0.51 – 0.70 means there is a moderate to high relationship, ± 0.71 – 0.99 means there is a high to very high relationship, and 1.00 means there is a perfect relationship (Johnson & Nelson, 1986, p. 35). Construct validity was established by comparing the front kick scores of 12 elite and 12 non-elite athletes using an independent t-test with a statistical significance of $p < 0.05$ (Gontara & Doewes, 2023).

Results

Figure 7 shows the results of the data normality test using Ryan-Joiner (RJ). The RJ test and retest values are > 0.05, which means that the data is normally distributed. Figure 8 shows the results of the next test, the correlation test using Pearson correlation. Test and retest showed a value of r = 0.923 which means there is a very high relationship.

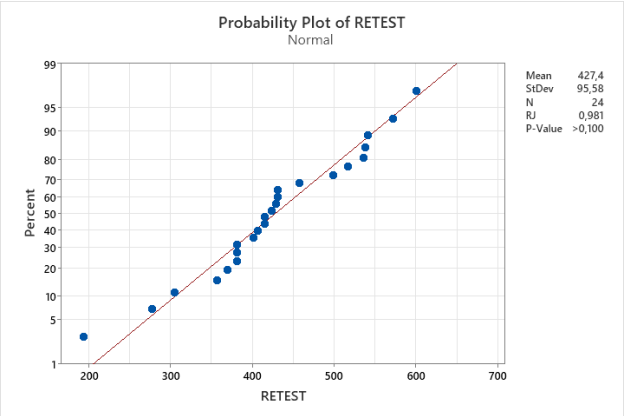


Figure 7. Normality test results of test and retest

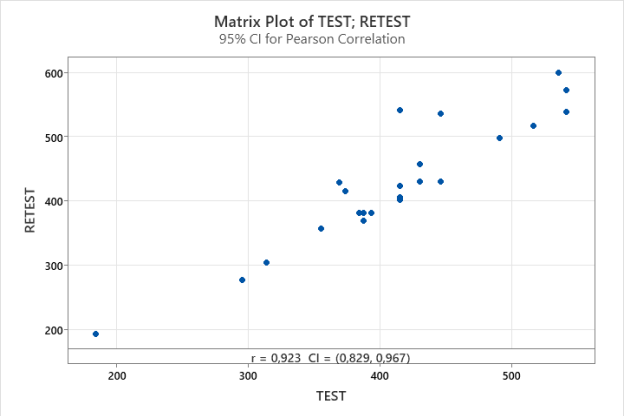


Figure 8. Pearson correlation test results

Table 1 shows the results of the independent t-test, which shows that there is a significant difference from the Inosen's Silat Momentum Test score with P-value < 0.05. Elite athletes have higher average test scores than non-elite athletes, with average scores of 463.3 kg.m/s and 375 kg.m/s. This can also be seen in the difference in average scores between elite and non-elite players, amounting to 88.3 kg.m/s.

Table 1.
Difference of front kicks scores using Inosen's Silat Momentum Test between elites and non-elites

Sample	N	Mean	Mean Difference	StDev	P-Value
ELITES	12	463.3 kg.m/s	88.3 kg.m/s	57.5 kg.m/s	0.009*
NON-ELITES	12	375.0 kg.m/s		90.9 kg.m/s	

*a significant difference was found between elites and non-elites (p < 0.05)

Discussion

This study tested a newly developed test and measurement tool for momentum kicks in the sparring category of Pencak Silat. The newly developed instrument is tested using the test-retest method to establish its reliability and construct validity. When comparing the test and retest results, the results showed a very high correlation on Inosen's Silat Momentum Test (r = 0.923). This means that the test has a consistent performance in measuring kicking momentum in both elite and non-elite athletes (Qu et al., 2024). By comparing the results of the front kick between the two

groups (elite and non-elite) for the validity test, the results showed a significant difference in the Inosen's Silat Momentum Test with P Value < 0.05. Elite athletes had higher mean scores than non-elite athletes with mean scores of 463.3 kg.m/s and 375 kg.m/s. This means Inosen's Silat Momentum Test is a test that can differentiate the quality of kick momentum of Pencak Silat athletes according to fighter performance (Gontara & Doewes, 2023). Furthermore, the difference is clearly influenced by the biomotor elements that produce speed and quality kicking techniques that will affect the mass involved in the kick (Fachrezzy et al., 2021; Ihsan et al., 2022). These factors are determined by the quality and duration of training (Izzo et al., 2022; Sinulingga, Pasaribu, et al., 2023). However, comprehensive research on the factors that affect kick momentum in Pencak Silat needs to be investigated further.

Sports technology has evolved rapidly over the past few decades, and today it affects almost all aspects of sports such as how athletes compete and train, how fans enjoy and engage in sporting events, and how managers organize their teams. As a result, the sports ecosystem is increasingly complex and increasingly reliant on advanced technology (Beiderbeck et al., 2023; Du et al., 2023; Fuss et al., 2008).

In Pencak Silat, there is room for new gears to be integrated and developed using advanced technology to optimize athlete development. For example, wearable devices that can detect some biological information related to performance support such as heart rate, blood pressure, electroencephalogram (EEG)/brain waves, biochemistry, and biomechanics (joint angle, force, etc.) can be adapted to monitor athlete's performance (Zhang et al., 2019). An example of a particularly helpful tool in Pencak Silat is a tool developed by Anifah et al. (2023). The tool is capable of performing automatic assessments using sensors that will help referees and judges in assessing every attack that takes place. Additionally, the alternate tool for the fighting category in Pencak Silat applies a sensor-based scoring system, which can aid the jury and Pencak Silat practitioners in facilitating their performance in giving an unbiased and transparent assessment (Ihsan et al., 2024).

Performance evaluation requires a touch of technology to ensure its validity, i.e., the match between what is measured and its measurement (Romagnoli et al., 2023). Another beneficial measuring tool also mentioned by Irawan that it belongs to an advanced sports technology for gathering sports data connecting hand-eye coordination (Irawan et al., 2024).

Currently, there are several tests and measurements of athlete performance that apply sophisticated technology, including measuring kick speed in Pencak Silat using simple kinematics analysis with cameras and Kinovea software to measure the distance and time traveled during kicks (Syaifullah & Maghribi, 2023). Another example is the kinetics analysis conducted by Diewald et al. (2022) and Menzel & Potthast (2021) which discussed the measurement of impact in martial arts strikes. Technology has played a key role in improving Pencak Silat's training and competition quality by significantly changing the way movements are understood, trainings are conducted, and judging is made. With wise use, technology continues to open opportunities for a better understanding of Pencak Silat and improvement of the quality of learning and competition (Sinulingga, Kasih, et al., 2023).

The test and measurement of Pencak Silat kicking momentum in the sparring category called Inosen's Silat Momentum Test has been compiled through systematic stages based on Johnson and Nelson's seven-steps test construction. In terms of conceptual design, the Inosen's Silat Momentum Test has been designed or arranged according to the concept resulting from factor analysis and tools selection that support the realization of the Inosen's Silat Momentum Test. The Inosen's Silat Momentum Test has undergone reliability and validity testing and has been found to be a reliable and valid tool for measurement. In addition, test procedures have been finalized and can be used as guidelines for operating and collecting data from Pencak Silat kick momentum testing and measurement in the sparring category. The Inosen's Silat Momentum Test has also referred to the SI standard from momentum measurement, namely kilogram meters per second (kg.m/s). With the help of sensor technology, all the required variables can be obtained in real time. Sensors are an appropriate tool to analyze performance by analyzing biomechanical parameters with the proper selection of the most suitable for each specific situation (Olaya-Cuartero et al., 2023).

Discussing tests, measurements, and evaluations in sports is important. Currently, sports tests and measurements have made significant progress, as evidenced by the development and creation of various modern test instruments (Chavarría-Fernández et al., 2023; Montoro-Bombú et al., 2022). However, many Pencak Silat practitioners still measure and evaluate athletes' abilities using an inappropriate method. For instance, in some studies, the kicking speed of Pencak Silat athletes is measured by counting the number of successful repetitions within a given time frame (Irnawati et al., 2022; Pomatahu, 2018). This practice will lead to a persisting error from generation to generation, which will then normalize the nomenclature error and allow nomenclature errors to occur in other variables because if we refer to the international system of units, the unit of speed is meters per second (m/s). This will certainly make it difficult for us as sports scientists to conduct multidisciplinary research in other scientific fields. The Inosen's Silat Momentum Test is the result of a multidisciplinary collaboration between sports science and engineering departments that has produced sports technology. As said by Worsey et al. (2019), the focus should now be on using specific performance algorithms in combination with multiple sensors to obtain more in-depth measurements of the biomechanics of martial sports. In this case, we are specifically referring to Pencak Silat.

Conclusions

Based on the findings, it is inferred that Inosen's Silat Momentum Test is a reliable and valid instrument for measuring the ability of Pencak Silat kick momentum. The units used to measure momentum are in accordance with the International System of Units (SI), specifically kilogram meters per second (kg.m/s). Inosen's Silat Momentum Test is a test that can differentiate the quality of kick momentum of Pencak Silat athletes according to fighter performance. Pencak Silat athletes employed in this research showed consistent results in Inosen's Silat Momentum Test. Thus, Inosen's Silat Momentum Test can be used to assess the kick momentum of Pencak Silat athletes.

Conflicts of interest

The authors declare no conflict of interest. No financial support was received.

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