

Design of a sensor technology-based hand-eye coordination measuring tool: Validity and reliability Diseño de una herramienta de medición para la coordinación ojo-mano basada en tecnología de sensores: validez y confiabilidad

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Abstract. This research aims to design a sensor-based hand-eye coordination measuring tool and test its validity and reliability. A total of 9 experts were involved in assessing its feasibility, each of them 3 sports measurement experts, 3 motor experts, and 3 technology experts. Meanwhile, 50 students at one of the Faculty of Sports Sciences, Indonesia participated in field trials. Participants were students taking physical condition courses (aged 18-20 years), consisting of male ($n_1=30$) and female ($n_2=20$). A validation questionnaire was prepared and discussed with experts as a guide in providing an assessment of the relevance of the instrument (suitability, accuracy, ease, and practicality of the tool), and test-retest reliability for field trials carried out twice with the difference between the first and second tests being one week. Data were analyzed using Aiken's V Index, Intraclass Correlation Coefficient (ICC), and Pearson correlation. The research results showed that the assessment of all aspects of the measuring instrument was in the high category, and the ICC value also showed no differences between assessments ($P>0.05$). Then, the test-retest reliability testing results obtained a significant regression analysis with a high correlation coefficient ($r=0.801$; $P<0.05$). In conclusion, this measuring tool can collect data to improve performance in sports involving hand-eye coordination (such as volleyball, badminton, tennis, basketball, hockey, martial arts and other sports that predominantly use the hands), both for coaches, athletes and sports practitioners.

Keywords: validity, reliability, coordination, sensors

Resumen. Esta investigación tiene como objetivo diseñar una herramienta de medición de la coordinación ojo-mano basada en sensores y probar su validez y confiabilidad. Para evaluar su viabilidad participaron un total de 9 expertos, cada uno de ellos 3 expertos en mediciones deportivas, 3 expertos en motricidad y 3 expertos en tecnología. Mientras, 50 estudiantes de una de las Facultades de Ciencias del Deporte de Indonesia participaron en pruebas de campo. Los participantes fueron estudiantes de cursos de condición física (de 18 a 20 años), compuestos por hombres ($n_1=30$) y mujeres ($n_2=20$). Se preparó un cuestionario de validación y se discutió con expertos como guía para proporcionar una evaluación de la relevancia del instrumento (idoneidad, precisión, facilidad y practicidad de la herramienta) y la confiabilidad test-retest para las pruebas de campo realizadas dos veces con la diferencia entre la primera y la segunda prueba hay una semana. Los datos se analizaron utilizando el índice V de Aiken, el coeficiente de correlación intraclass (ICC) y la correlación de Pearson. Los resultados de la investigación mostraron que la evaluación de todos los aspectos del instrumento de medición estuvo en la categoría alta, y el valor ICC tampoco mostró diferencias entre evaluaciones ($P>0.05$). Luego, los resultados de las pruebas de confiabilidad test-retest obtuvieron un análisis de regresión significativo con un alto coeficiente de correlación ($r=0.801$; $P<0.05$). En conclusión, esta herramienta de medición se puede utilizar en la recopilación de datos para mejorar el rendimiento en deportes que implican coordinación ojo-mano (como voleibol, bádminton, tenis, baloncesto, hockey, artes marciales y otros deportes que utilizan predominantemente las manos), tanto para Entrenadores, atletas y practicantes de deporte.

Palabras Clave: validez, confiabilidad, coordinación, sensors

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Introduction

Hand-eye coordination is an essential skill in specific sports activities (Antara et al., 2023), and is directly related to visual reactions, timing speed, and motor responses (Schwab & Memmert, 2012). This approach has been demonstrated to benefit athletes during competition (Ceylan & Saygin, 2015; Chang, Tsai, Chen, & Hung, 2013), as it enhances the ability to produce complex movements (Paul, Biswas, & Singh, 2011).

Decisions are often made quickly based on the presentation of various visual stimuli (Schwab & Memmert, 2012). The more complex the movement, the higher the level of coordination required. The importance of hand-eye coordination in various sporting contexts has also been investigated, such as goalkeeping in football (Nagano, Kato, & Fukuda, 2004), dribbling in hockey (Antara et al., 2023), defence in basketball (Laurent, Ward, Williams, & Ripoll, 2006), and general movements that involve hand-

eye coordination in other sports, such as passing, throwing and hitting (Zupan & Wile, 2011). Thus, measuring hand-eye coordination becomes essential in collecting data to improve performance in sports involving these basic physical abilities.

Currently, the use of technology in sports is increasing (Kim & Ko, 2019; Szymanski, Wolfe, Danis, Lee, & Uy, 2020), and its innovation have become an essential part (Alnedral, Ihsan, Mario, Aldani, & Sari, 2023; Handayani, Myori, Yulifri, Komaini, & Mario, 2023; Ratten, 2020). This aims to reduce errors in data collection (Firdaus & Mario, 2022), and facilitate performance improvements (Ferreira, Fernandes, Ratten, & Miragaia, 2020; Wang, Chen, & Lin, 2015). Additionally, wearable device sensor technology in sports has been reported to address injury prevention, motion analysis, technique classification, and performance assessment (Adesida, Papi, & Mcgregor, 2019; Firdausi, Andriadi, Dwisaputra, & Simbolon, 2023).

From youth sports and recreational activities to elite athletes (Adesida et al., 2019; Rana & Mittal, 2020; Stetter, Ringhof, Krafft, Sell, & Stein, 2019) apply these devices to monitor total exposure over time during a training session, a training period or entire season, and most often in team sports (Benson et al., 2020; Heishman et al., 2020; Mcfadden, Walker, Bozzini, Sanders, & Arent, 2020; Rico-González, Arcos, Rojas-Valverde, Clemente, & Pino-Ortega, 2020), and run (Davis & Gruber, 2019; Napier, Ryan, Menon, & Paquette, 2020; Ryan, Napier, Greenwood, & Paquette, 2020).

Regarding to hand-eye coordination measuring devices, various companies have marketed devices that they claim can be used to measure and improve hand-eye coordination (e.g. Sports Vision Trainer (SVT), Sports Vision Pty Ltd, Australia; Dynavision D2, Dynavision International LLC, USA; Wayne Saccadic Fixator, Wayne Engineering, USA; Batak Pro, Quotronics Limited, UK) (Ellison, Kearney, Sparks, Murphy, & Marchant, 2018). Sherman has applied the Wayne Saccadic Fixator to evaluate hand-eye visual-motor reaction times (Laby, Kirschen, Govindarajulu, & Deland, 2018). This study reported that out of 16 college sports populations (baseball players) had better hand-eye visual-motor reaction times in the college group. However, the study should have reported details regarding the levels of college and professional players.

Ellison et al (Ellison, Sparks, Murphy, Carnegie, & Marchant, 2014) utilized SVT to assess hand-eye coordination. The report found that hand-eye coordination measurements were reliable using SVT. Then, a Batak Pro device to measure reaction and hand-eye coordination (Millard, Shaw, Breukelman, & Shaw, 2021; Quotronics, 2011), where individuals can process and act on visual information (Lobier, Dubois, & Valdois, 2013). Batak Pro is an LED lighting fixture used for each stimulus on one of each target (Ellison et al., 2018). However, data is rarely reported on young athletes.

Additional studies such as Sonar et al (Sonar, Sawant, Salunkhe, & Baraskar, 2022), who developed an hand-eye coordination device using a pen (sensor), tested the reliability of an hand-eye coordination test using a camera (Rozan, Sidik, Sunar, & Omar, 2015), and investigated inertial sensor devices in assessing the development of locomotor skills in childhood (Masci et al., 2013). Meanwhile, the traditional hand-eye coordination test that is often used by researchers is the Hand Wall Toss Test (Ashok, 2008). This test is carried out by throwing the ball towards the wall using the right hand and catching it with the left hand or vice versa. Thus, sensor-based hand-eye coordination measurement tools must be designed to support relevant research developments in improving sports performance.

This research aims to design a sensor-based hand-eye coordination measuring tool and test its validity and reliability. Sensor-based hand-eye coordination measuring tools and field testing must be designed to support the development of relevant studies on improving sports performance.

This tool is expected to help collect data to improve performance in sports that involve hand-eye coordination (such as volleyball, badminton, tennis, basketball, hockey, martial arts and other sports where hands are dominant), both for coaches, athletes and sports practitioners.

Methods

Design and participants

This research and development, research aims to design a sensor-based hand-eye coordination measuring tool and test its validity and reliability. A total of 9 experts participated assessing its feasibility, each of whom was 3 sports measurement experts, 3 motor experts, and 3 technology experts. The experts are lecturers at Universitas Negeri Padang, Indonesia, namely the Faculty of Sports Science and Engineering. The experts are doctors and professors with \pm 5 years of experience in their respective fields. Then, 50 students at the Faculty of Sports Science, Indonesia, were also involved in field trials. Participants were students taking physical condition courses, who participated voluntarily and complied with the provisions before and during the test. Participants consisted of male ($n_1=30$; 19.07 ± 0.83 years; 63.33 ± 3.94 kg; 169.93 ± 3.45 cm; and BMI 21.93 ± 1.26) and female ($n_2=20$; 18.85 ± 0.81 years; 59.45 ± 2.67 kg; 164.50 ± 2.44 cm; and BMI 21.98 ± 1.02).

Procedures and instruments

The procedures in this research include designing and developing the tool's shape, testing and refining the tool, and field trials. The sensor-based hand-eye coordination test measuring tool is designed by technology experts or non-experts who are involved in assessing the tool's suitability. This is to avoid conflicts of interest. The components of the tool design consist of a steel frame, a series of touch sensors, an LCD, and a carpet for the testee to stand on. Other components are Arduino Mega, TFT LCD (3.5 inches), power supply unit, voltage regulator, vibration sensor, LED lamp (5 watts), CB connector, and relay module. Indicators for assessing measuring instruments that have been designed are presented in the form of a questionnaire that was prepared and discussed with experts as a guide in assessing the instrument's relevance (suitability, accuracy, ease and practicality) (Table 1). This validation aims to determine the designed tool's accuracy and suitability so that it can measure what it should measure. The validation results and comments from experts were discussed for improvement until there was an agreement for field trials. This field trial was conducted to determine the measuring instrument's reliability in collecting sensor-based hand-eye coordination test data. This reliability test uses the test-retest method, with two repetitions of the test. The first and second tests were carried out one week apart under the same conditions and participant situations during both tests.

The instructions for carrying out this sensor-based hand-eye coordination test are: (a) the testee stands in a prepared

area measuring 75 cm, (b) the testee stands in a ready position, legs straight and shoulder-width apart when turning off the sensor, (c) the distance between each sensor was 30-50 cm (the distance of the inner sensor from the centre of the screen was 30 cm, and the outer one was 50 cm), (d) the test begins when there is a "sound" signal on the tool, (e) the testee makes a movement with both hands open to turn off or press the sensor that is on randomly, (f) the test execution time was 60 seconds, and (g) the score taken is the best score from two repetitions (the score will appear in the middle of the screen) (Figure 1).

Table 1. Expert assessment instruments

Aspect	Tool assessment items
Suitability	Procedures in tool design are based on appropriate norms. The measurement aims to determine the level of hand-eye coordination.
	The measurement results are in the form of a number (score) over a specified time. The equipment designed is an innovation from sports technology. Suitability of components used for tool design.
Accuracy	The working principle of the tool is designed based on test and measurement studies. The tool is designed based on evaluation needs for measuring hand-eye coordination.
	The tool is designed for sports that involve hand-eye coordination. The tool's shape is a prototype and can be developed further. The tool's working system is designed per the concept of coordination theory. The tool is designed for males and females.
Ease	Ease of operating the tool system. The tools are attractively designed and uncomplicated. The output on the LCD screen is displayed clearly. The tool can be used indoors or outdoors.
	The tool design has accurate measurements. The tools designed have instructions for their use.
Practicality	The tool design is very practical, effective and efficient. The energy source in the designed tool is easy to obtain. The tool design has effective size.

The scoring alternatives are a score of 5 for very valid, a score of 4 for valid, a score of 3 for enough valid, a score of 2 for less valid, and a score of 1 for invalid.

Table 2. Categories for V index, ICC, and correlation

V	Category	ICC	Category	r	Category
V > 0.8	High	> 0.90	Very high	0.90 < 1.00	Very high
0.4 ≤ V ≤ 0.8	Enough	0.76-0.90	High	0.80 < 0.89	High
V < 0.4	Low	0.50-0.75	Enough	0.60 < 0.79	Currently Not acceptable
		< 0.50	Low	0.00 < 0.59	

Statistical analysis

Validation from experts was analyzed using Aiken's V index (Aiken, 1985) and ICC to analyze whether or not there are differences in assessments between experts (Koo & Li, 2016) (Table 2). Then, test-retest reliability was analyzed

Table 3. V Index

Aspect	Items	Raters										Σs	n(c-1)	V Index	M ± SD
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	S ₉					
Suitability	1	4	4	3	4	4	4	3	4	4	34	36	0.944	0.967 ± 0.050	
	2	4	4	4	4	4	4	4	4	4	36	36	1,000		
	3	4	4	4	4	4	4	4	4	4	36	36	1,000		
	4	4	4	4	4	4	4	4	4	4	36	36	1,000		
	5	4	4	3	3	4	4	3	3	4	32	36	0.889		
Accuracy	1	4	4	4	4	3	3	4	4	4	34	36	0.944	0.870 ± 0.102	
	2	3	4	4	3	3	4	4	3	4	32	36	0.889		
	3	4	4	4	3	4	4	3	4	3	33	36	0.917		

using the Pearson correlation coefficient. This stage uses IBM SPSS version 24 software.

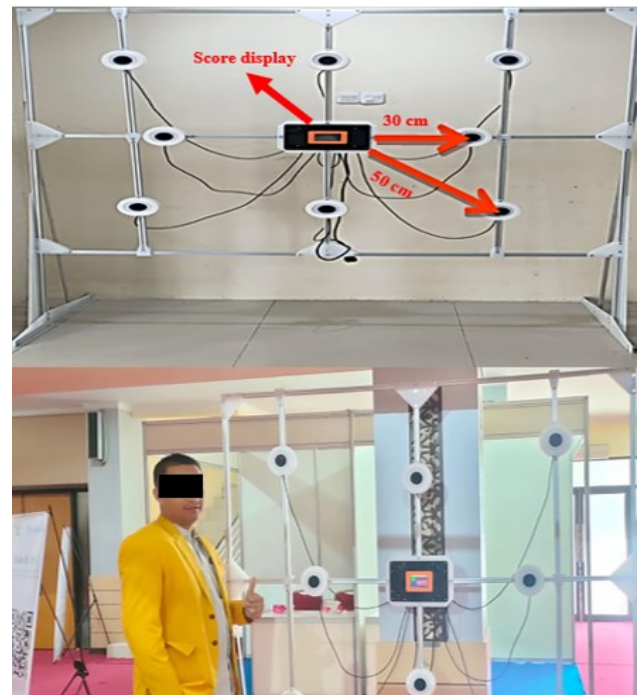


Figure 1. Sensor-based hand-eye coordination measuring tool

Results

Tool validity

The experts' assessment of the sensor-based hand-eye coordination measuring tool from all aspects was obtained in the high category ($V = 0.894$). Meanwhile, in each aspect, the tool's suitability, accuracy, ease, and practicality were good ($V = 0.967$; $V = 0.870$; $V = 0.840$; and $V = 0.894$) (Table 3). Then, the ICC value also shows that there is no difference in the assessments given between experts, both for all aspects and every aspect ($P > 0.05$) (Table 4). This is also proven by the ICC values of all aspects of the assessment ($ICC = 0.844$) and each aspect ($ICC = 0.773$; $ICC = 0.824$; $ICC = 0.897$; and $ICC = 0.574$) (Table 5). Some comments from technology experts regarding the revision of the tool are: (a) the colour of the sensor is too bright, (b) the frame size of the measuring tool is too small, so that the tool is not sturdy when participants carry out the test, which has an impact on turning on/off the sensor, and (c) the display size on the measuring instrument needs to be enlarged. This revision was carried out and discussed with experts until an agreement was reached for field trials.

	4	3	3	2	3	3	3	2	2	3	24	36	0.667
	5	4	4	3	4	3	3	4	4	4	33	36	0.917
	6	4	4	3	4	4	3	4	3	3	32	36	0.889
Ease	1	4	4	3	4	4	3	4	3	3	32	36	0.889
	2	4	4	4	4	3	4	3	4	4	34	36	0.944
	3	4	3	2	2	2	2	3	2	3	23	36	0.639
	4	4	3	4	4	3	3	4	3	4	32	36	0.889
Practicality	1	4	4	4	4	4	3	4	4	4	35	36	0.972
	2	3	4	3	3	3	4	3	3	3	29	36	0.806
	3	4	3	4	3	4	3	4	3	4	32	36	0.889
	4	4	4	4	3	4	3	4	4	3	33	36	0.917
	5	4	3	4	4	3	3	4	3	4	32	36	0.889
All aspects	77	75	70	71	70	68	72	68	73	644	36		0.894 ± 0.096

"S" is the score assigned to each rater and minus the lowest score in the category, "V" is the agreement index of the rater.

Table 4. ANOVA

Source	SS	Df	MS	F	P
Between People*	1.422	4	0.356		
Within People	Between Items	1.200	8	0.150	1.862 0.102
	Residual	2.578	32	0.081	
	Total	3.778	40	0.094	
Between People**	7.481	5	1.496		
Within People	Between Items	1.481	8	0.185	0.704 0.686
	Residual	10.519	40	0.263	
	Total	12.000	48	0.250	
Between People***	8.083	3	2.694		
Within People	Between Items	3.556	8	0.444	1.600 0.177
	Residual	6.667	24	0.278	
	Total	10.222	32	0.319	
Between People****	2.089	4	0.522		
Within People	Between Items	1.778	8	0.222	1.000 0.455
	Residual	7.111	32	0.222	
	Total	8.889	40	0.222	
Between People*****	25.022	19	1.317		
Within People	Between Items	3.711	8	0.464	1.726 0.112
	Residual	31.178	152	0.205	
	Total	34.889	160	0.218	

"SS" is the Sum of Squares; "MS" is the Mean Square; There were no differences in assessments between experts ($P > 0.05$). *suitability **accuracy ***ease ****practicality *****all aspects.

Table 5. Intraclass Correlation Coefficient

Source	ICC ^b	CI (95%)		F		
		Lower B	Upper B	Value	df1	df2
SM	0.275 ^a	0.040	0.801	4.414	4	32
AM*	0.773 ^c	0.271	0.973	4.414	4	32
SM	0.343 ^a	0.096	0.791	5.690	5	40
AM**	0.824 ^c	0.490	0.972	5.690	5	40
SM	0.492 ^a	0.151	0.938	9.700	3	24
AM***	0.897 ^c	0.616	0.993	9.700	3	24
SM	0.130 ^a	-0.031	0.677	2.350	4	32
AM****	0.574 ^c	-0.370	0.950	2.350	4	32
SM	0.376 ^a	0.219	0.592	6.421	19	152
AM*****	0.844 ^c	0.717	0.929	6.421	19	152

"CI" is the Confidence Interval; "ICC" is the Intraclass Correlation Coefficient; "SM" is Single Measures; "AM" is Average Measures; Significant ($P < 0.05$).

*suitability **accuracy ***ease ****practicality *****all aspects.

a. The estimator is the same, whether the interaction effect is present.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Tool reliability

The results of the test-retest reliability test obtained a correlation coefficient in the high category ($r = 0.801$, $F = 86.038$; $t = 9.276$; $n = 50$; $P < 0.05$). The correlation coefficient for male participants is in the enough category ($r = 0.711$; $F = 28.608$; $t = 5.349$; $n = 30$; $P < 0.05$), and for females is in the very high category ($r = 0.943$; $F = 145.174$; $t = 12.049$; $n = 20$; $P < 0.05$). The regression analysis and relationship also showed significance ($P < 0.05$) (Table 6). Then, the linearity curve of each of these tests is presented in Figure 2.

Table 6. Test-retest reliability

Gender	N	R	F	P	T	P
Male	30	0.711	0.000	28.608	0.000	5.349
Female	20	0.943	0.000	145.174	0.000	12.049
Total	50	0.801	0.000	86.038	0.000	9.276

"R" is the correlation coefficient; "F" is the regression significance; "t" is the significance of the relationship; significant ($P < 0.05$).

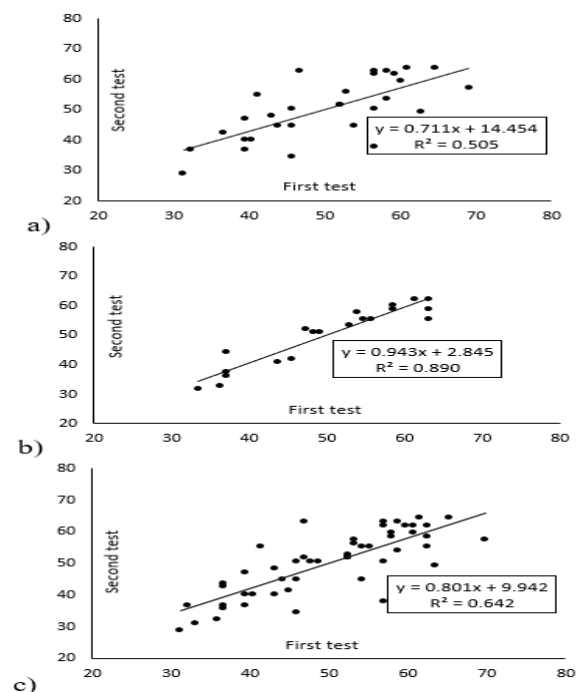


Figure 2. a) linearity curve for test-retest in male participants, b) linearity curve for test-retest in female participants, and c) linearity curve for test-retest in male and female participants

Discussion

The design of this sensor-based hand-eye coordination measuring instrument has high test-retest validity and reliability ($V = 0.894$; $r = 0.801$; $P < 0.05$). Regression analysis and the relationship between the first and second tests also showed significant results ($P < 0.05$). The first and second tests were conducted one week apart under the same conditions and participant situations. The study Sonar et al (Sonar et al., 2022) develops and produces portable hand-eye coordination equipment with reliable readings. Rozan et al (Rozan et al., 2015), also tested the reliability of a hand-eye coordination test using a reliable camera. It involved 33 rugby players aged 16 to 18 years, and the test was carried out twice, 6 to 7 days apart. Thus, this hand-eye coordination measuring tool is also consistent in collecting data.

This tool is an innovation in sports technology for collecting data in sports involving hand-eye coordination (such as volleyball, badminton, tennis, basketball, hockey, martial arts and other sports where hands are dominant). This includes game sports in physical education as well (Firdaus et al., 2023; Umar, Alnedral, Ihsan, Mario, & Mardesia, 2023; Welis, Yendrizal, Darni, & Mario, 2023). Previous studies reported that technology in the sports sector is a complex system for collecting and processing large amounts of data (Camomilla, Bergamini, Fantozzi, & Vannozzi, 2018; Ratten, 2020). It aims to improve sports performance, where its use has been proven effective in sports training (Firdaus & Mario, 2022; Handayani et al., 2023; Kokarev, Kokareva, Atamanuk, Terehina, & Putrov, 2023; Lisenchuk et al., 2023; Oh, Johnson, & Syrop, 2019). Another study reported that sensor technology benefits transparent and objective measurement results (Eitzen, Renberg, & Færevik, 2021).

The absolute assessment that must be fulfilled in developing an instrument or measuring tool is validity and reliability (Rifki et al., 2022; Susiono et al., 2024). Validity refers to the accuracy of what the instrument is intended to measure, while reliability refers to the consistency of data obtained repeatedly in the same situation (Heale & Twycross, 2015; Lexell & Downham, 2005). According to Almanasreh et al (Almanasreh, Moles, & Chen, 2019), content validity is the minimum requirement for all instruments developed. Content validity is different from other types of validity. It describes what is required of the instrument's content and is not related to the scores obtained on the constructs (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).

This measuring instrument was validated by 9 experts, each of whom provided an assessment regarding the relevance of the instrument independently (Heale & Twycross, 2015; Larsson et al., 2015). Previous studies reported that involvement and a more significant number of experts will reduce the possibility of coincidental agreement so that the information provided from instrument development will be better (Rubio, Berg-weger, Tebb, Lee, & Rauch, 2003). Inter-expert assessment of the designed measuring instruments

also showed no differences, where ICC was used to analyze this. According to Almanasreh et al (Almanasreh et al., 2019), the content validity index and other types of construct validation are equally important in developing an instrument, so this must be done. Meanwhile, the participation and involvement of experts in providing assessments must be based on clear criteria (for example, relevant expertise, qualifications and experiences). This will impact the assessment results and comments on the contents of an instrument being developed (Almanasreh et al., 2019).

The stages of designing this measuring instrument have been attempted as closely as possible. However, several limitations need to be reported. This measuring tool was only tested on participants aged 18 years and over, and norms/classifications for hand-eye coordination tests have yet to be prepared for this test. This research is designed for the first year funded by the institution, and in the second year, it will be planned to test measuring instruments on a large scale with different age groups. The operation involves IP address with web browser applications. Then, test norms need to be displayed on the measuring instrument to determine the level of hand-eye coordination.

Conclusion

The conclusion from these findings is the creation of a sensor-based hand-eye coordination measuring tool that meets the feasibility criteria, namely validity and reliability. This measuring tool was assessed by experts before being tested (sports measurement, motor and technology), with the V index in the high category ($V = 0.894$) and the ICC value also showed that there were no differences in assessments between experts ($P > 0.05$). Then, the results of test-retest reliability testing obtained a high correlation coefficient ($r = 0.801$; $P < 0.05$), with regression analysis and a significant relationship ($P < 0.05$). The hand-eye coordination test on this tool is carried out in a standing position at 30-50 cm from each sensor. Turning on or off the sensor on the tool is carried out randomly, and the testee does this by pressing small circles. The test execution time and the number of sensors the testee has successfully turned off will be displayed on the screen. This tool can collect data to improve performance in sports involving hand-eye coordination (such as volleyball, badminton, tennis, basketball, hockey, martial arts and other sports where hands are dominant), both for coaches, athletes and sports practitioners. Future research is needed to test sensor-based hand-eye coordination measures on a large scale with different age groups.

Conflict of interest

The authors report no potential conflicts of interest.

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References

- Adesida, Y., Papi, E., & Mcgregor, A. H. (2019). Exploring the role of wearable technology in sport kinematics and kinetics: A systematic review. *Sensors*, *19*(7), 1597. <https://doi.org/10.3390/s19071597>
- 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, A., 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>
- Antara, R., Welis, W., Masrun, M., Irawan, R., Mario, D. T., Alnedral, ... Wąsik, J. (2023). Effects of agility, coordination, and flexibility on dribbling skills in senior high school female field hockey players. *Physical Activity Review*, *11*(2), 42–51. <https://doi.org/10.16926/par.2023.11.20>
- Ashok, C. (2008). *Test your physical fitness*. Gyan Publishing House.
- Benson, L. C., Tait, T. J., Befus, K., Choi, J., Hillson, C., Stilling, C., ... Emery, C. A. (2020). Validation of a commercially available inertial measurement unit for recording jump load in youth basketball players. *Journal of Sports Sciences*, *38*, 928–936. <https://doi.org/10.1080/02640414.2020.1737360>
- 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>
- Ceylan, H. I., & Saygin, O. (2015). Examining the effects of proprioceptive training on coincidence anticipation timing, reaction time and hand-eye coordination. *Anthropologist*, *20*(3), 437–445. <https://doi.org/10.1080/09720073.2015.11891747>
- Chang, Y. K., Tsai, Y. J., Chen, T. T., & Hung, T. M. (2013). The impacts of coordinative exercise on executive function in kindergarten children: An ERP study. *Experimental Brain Research*, *225*(2), 187–196. <https://doi.org/10.1007/s00221-012-3360-9>
- Davis, J. J., & Gruber, A. H. (2019). Quantifying exposure to running for meaningful insights into running-related injuries. *BMJ Open Sport Exercise Medicine*, *5*, 1–4. <https://doi.org/10.1136/bmjsem-2019-000613>
- Eitzen, I., Renberg, J., & Færevik, H. (2021). The use of wearable sensor technology to detect shock impacts in sports and occupational settings: A scoping review. *Sensors*, *21*(1), 1–29. <https://doi.org/10.3390/s21154962>
- Ellison, P. H., Kearney, P. E., Sparks, S. A., Murphy, P. N., & Marchant, D. C. (2018). Further evidence against eye–hand coordination as a general ability. *International Journal of Sports Science and Coaching*, *13*(5), 687–693. <https://doi.org/10.1177/1747954117747132>
- Ellison, P. H., Sparks, S. A., Murphy, P. N., Carnegie, E., & Marchant, D. C. (2014). Determining eye–hand coordination using the sport vision trainer: An evaluation of test–retest reliability. *Research in Sports Medicine*, *22*(1), 36–48. <https://doi.org/10.1080/15438627.2013.852090>
- Ferreira, J. J., Fernandes, C., Ratten, V., & Miragaia, D. (2020). Sports innovation: A bibliometric study. *Sport Entrepreneurship and Public Policy: Building a New Approach to Policy-Making for Sport*, 153–170. https://doi.org/10.1007/978-3-030-29458-8_10
- Firdaus, K., Hartoto, S., Hariyanto, A., Subagya, I., Nikmatullaili, Mario, D. T., & Zulfahri. (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>
- Firdausi, D. K. A., Andriadi, A., Dwisaputra, I., & Simbolon, M. E. M. (2023). Tablero automático de pase de pecho para evaluar las habilidades básicas de pase de pecho usando un sensor de vibración (Chest pass automatic board for evaluating basic chest pass skills using vibration sensor). *Retos*, *50*, 931–935. <https://doi.org/10.47197/retos.v50.94808>
- 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>
- Heale, R., & Twycross, A. (2015). Validity and reliability in quantitative studies. *Evidence-Based Nursing*, *18*(3), 66–67. <https://doi.org/10.1136/eb-2015-102129>
- Heishman, A., Peak, K., Miller, R., Brown, B., Daub, B., Freitas, E., & Bembem, M. (2020). Associations between two athlete monitoring systems used to quantify external training loads in basketball players. *Sports*, *8*(3), 1–11. <https://doi.org/10.3390/sports8030033>
- Kim, D., & Ko, Y. J. (2019). The impact of Virtual Reality (VR) technology on sport spectators' flow experience and satisfaction. *Computers in Human Behavior*, *93*, 346–

356. <https://doi.org/10.1016/j.chb.2018.12.040>
- Kokarev, B., Kokareva, S., Atamanuk, S., Terehina, O., & Putrov, S. (2023). Effectiveness of innovative methods in improving the special physical fitness of qualified athletes in aerobic gymnastics. *Journal of Physical Education and Sport*, 23(3), 622–630. <https://doi.org/10.7752/jpes.2023.03077>
- Koo, 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>
- Laby, D. M., Kirschen, D. G., Govindarajulu, U., & Deland, P. (2018). The hand-eye coordination of professional baseball players: The relationship to batting. *Optometry and Vision Science*, 95(7), 557–567. <https://doi.org/10.1097/OPX.0000000000001239>
- Larsson, H., Tegern, M., Monnier, A., Skoglund, J., Helander, C., Persson, E., ... Aasa, U. (2015). Content validity index and intra- and inter- rater reliability of a new muscle strength/endurance test battery for Swedish soldiers. *PLoS ONE*, 10(7), 1–13. <https://doi.org/10.1371/journal.pone.0132185>
- Laurent, E., Ward, P., Williams, A. M., & Ripoll, H. (2006). Expertise in basketball modifies perceptual discrimination abilities, underlying cognitive processes, and visual behaviours. *Visual Cognition*, 13(2), 247–271. <https://doi.org/10.1080/13506280544000020>
- Lexell, J. E., & Downham, D. Y. (2005). How to assess the reliability of measurements in rehabilitation. *American Journal of Physical Medicine & Rehabilitation*, 84(9), 719–723. <https://doi.org/10.1097/01.phm.0000176452.17771.20>
- Lisenchuk, G., Leleka, V., Bogatyrev, K., Kokareva, S., Adamenko, O., Shchekotylyna, N., ... Krupenya, S. (2023). Fitness training in functional preparedness of highly qualified football players. *Journal of Physical Education and Sport*, 23(2), 502–509. <https://doi.org/10.7752/jpes.2023.02062>
- Lobier, M., Dubois, M., & Valdois, S. (2013). The role of visual processing speed in reading speed development. *PLoS ONE*, 8(4), e58097. <https://doi.org/10.1371/journal.pone.0058097>
- Masci, I., Vannozzi, G., Bergamini, E., Pesce, C., Getchell, N., & Cappozzo, A. (2013). Assessing locomotor skills development in childhood using wearable inertial sensor devices: the running paradigm. *Gait & Posture*, 37(4), 570–574. <https://doi.org/10.1016/j.gaitpost.2012.09.017>
- Mcfadden, B. A., Walker, A. J., Bozzini, B. N., Sanders, D. J., & Arent, S. M. (2020). Comparison of internal and external training loads in male and female collegiate soccer players during practices vs. games. *Journal of Strength and Conditioning Research*, 34(4), 969–974. <https://doi.org/10.1519/jsc.0000000000003485>
- Millard, L., Shaw, I., Breukelman, G. J., & Shaw, B. S. (2021). Differences in visio-spatial expertise between 1st division rugby players and non-athletes. *Heliyon*, 7(2), e06290. <https://doi.org/10.1016/j.heliyon.2021.e06290>
- Nagano, T., Kato, T., & Fukuda, T. (2004). Visual search strategies of soccer players in one-on-one defensive situations on the field. *Perceptual & Motor Skills*, 99(3), 968–974.
- Napier, C., Ryan, M., Menon, C., & Paquette, M. R. (2020). Session rating of perceived exertion combined with training volume for estimating training responses in runners. *Journal of Athletic Training*, 55(12), 1285–1291. <https://doi.org/10.4085/1062-6050-573-19>
- 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>
- Paul, M., Biswas, S. K., & Singh, S. J. (2011). Role of sports vision and eye hand coordination training in performance of table tennis players. *Brazilian Journal of Biomotricity*, 5(2), 106–116.
- 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. *Research in Nursing & Health*, 30(4), 459–467. <https://doi.org/10.1002/nur.20199>
- Quotronics, L. (2011). *Batak pro manual*. Surrey, United Kingdom.
- Rana, M., & Mittal, V. (2020). Wearable sensors for real-time kinematics analysis in sports: A review. *IEEE Sensors Journal*, 21(2), 1187–1207. <https://doi.org/10.1109/JSEN.2020.3019016>
- Ratten, V. (2020). Sport technology: A commentary. *The Journal of High Technology Management Research*, 31(1), 1–6. <https://doi.org/10.1016/j.hitech.2020.100383>
- Rico-González, M., Arcos, A. L., Rojas-Valverde, D., Clemente, F. M., & Pino-Ortega, J. (2020). A survey to assess the quality of the data obtained by radio-frequency technologies and microelectromechanical systems to measure external workload and collective behavior variables in team sports. *Sensors*, 20(8), 1–16. <https://doi.org/10.3390/s20082271>
- 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>
- Rozaan, M. R., Sidik, M. K. M., Sunar, M. S., & Omar, A. H. (2015). KIHECT©: Reliability of hand-eye coordination among rugby players using consumer depth camera. In *Computational Intelligence in Information Systems: Proceedings of the Fourth INNS Symposia Series on Computational Intelligence in Information Systems*, 201–210. https://doi.org/10.1007/978-3-319-13153-5_20
- Rubio, D. M., Berg-weger, M., Tebb, S. S., Lee, E. S., &

- Rauch, S. (2003). Objectifying content validity: Conducting a content validity study in social work research. *Social Work Research*, 27(2), 94–104.
- Ryan, M. R., Napier, C., Greenwood, D., & Paquette, M. R. (2020). Comparison of different measures to monitor week-to-week changes in training load in high school runners. *International Journal of Sports Science & Coaching*, 16, 370–379. <https://doi.org/10.1177/1747954120970305>
- Schwab, S., & Memmert, D. (2012). The impact of a sports vision training program in youth field hockey players. *Journal of Sports Science & Medicine*, 11(4), 624.
- Sireci, S. G., & Faulkner-Bond, M. (2014). *Validity evidence based on test content*. Psicothema.
- Sonar, A. D., Sawant, N., Salunkhe, J., & Baraskar, S. S. (2022). Design, development, and validation of hand-eye coordination equipment. *IETE Journal of Research*, 1–9. <https://doi.org/10.1080/03772063.2022.2055659>
- Stetter, B. J., Ringhof, S., Krafft, F. C., Sell, S., & Stein, T. (2019). Estimation of knee joint forces in sport movements using wearable sensors and machine learning bernd. *Sensors*, 19(17), 1–12. <https://doi.org/10.3390/s19173690>
- Susiono, R., Sugiyanto, F., Lumintuarso, R., Tomoliyus, T., Sukanti, E. R., Fauzi, F., ... Prabowo, T. A. (2024). Y Innovación en pruebas de agilidad en deportistas especiales de bádminton para la categoría junior (U17): validez y confiabilidad (Y agility test innovation on special badminton athletes for the junior category (U17): Validity and reliability). *Retos*, 53, 547–553. <https://doi.org/10.47197/retos.v53.103282>
- Szymanski, M., Wolfe, R. A., Danis, W., Lee, F., & Uy, M. A. (2020). Sport and international management: Exploring research synergy. *Thunderbird International Business Review*, 63(2), 253–266. <https://doi.org/10.1002/tie.22139>
- 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>
- Wang, Z. L., Chen, J., & Lin, L. (2015). Progress in triboelectric nanogenerators as new energy technology and self-powered sensors. *Energy and Environmental Science*, 8(8), 2250–2282. <https://doi.org/10.1039/c5ee01532d>
- 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>
- Yaakop, N., Koh, D., & Yasin, M. (2023). Una validación del contenido de las discusiones de grupos focales basada en el análisis de necesidades en un módulo de formación en educación física para profesores de escuela primaria (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>
- Zupan, M., & Wile, A. (2011). Eyes on the prize. *Training and Conditioning*, 21(2), 11–15.

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