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Development of a sit-up test instrument based on Kinect camera

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ABSTRACT

This study aimed to develop a sit-up test instrument using a Kinect camera to accurately measure performance and evaluate the quality of sit-up movements. It used a Research and Development (R&D) design. The subjects consisted of 55 male athletes aged 15-22 years, representing several sports, namely rowing, diving, volleyball, football, table tennis and Sepak Takraw, with an average height of ± 177.8 cm, average body weight ± 67.9 kg. Product testing was first conducted on a small group of 15 participants, followed by a re-test on a larger group of 40 participants. This process aimed to evaluate the consistency and readiness of the developed product. The study involved three experts in sports testing, biomechanics, and software to assess the validity, practicality, and effectiveness of the designed product. From the results of the assessment, the sports test and measurement expert received a score of 81, the sports biomechanics expert is 87 and the software expert is 86. The Cronbach's alpha (α) values are 0.82 and 0.78, required for reliability. The Kinect camera-based sit-up test instrument was found to be effective and efficient to use, with results that are valid and reliable in the very good category. However, a limitation of this tool is that it cannot be used outdoors, as the Kinect camera is not optimal for capturing movements under sunlight.

KEYWORDS

Kinect Camera; Sit-Ups; Test Instrument

1. INTRODUCTION

Sport is an indicator of someone being able to improve the quality of their body's physical fitness, because by having good physical fitness, a person has the potential to be able to live a better life (Kalb et al., 2020). Physical fitness are important factors for a healthy life over time (Kurt et al., 2024), and this is related to physical activity, because several studies show that physical activity has an influence on physical fitness (Lopez-Sanchez et al., 2019; Mora-Gonzalez et al., 2019; Vancampfort et al., 2019). Regular physical activity aims to maintain and improve body health (Mashud et al., 2024), This is because physical fitness is a factor that influences physical activity behavior (del Rocío Medrano Ureña et al., 2023). Physicality is the foundation of sporting achievement because technique, tactics and mentality can be developed well if you have good physical quality, and this of course must be an important concern, because it starts from the consequences of lifestyle habits (Rodriguez-Fuentes et al., 2022). A performance test is a collection of measurements used in sports science and coaching science to identify an individual's physical fitness, health state, or sport-specific ability (Currell & Jeukendrup, 2008; Robertson et al., 2014). Physicality plays a major role in the training process, with good physical technique, tactics and mental abilities can improve along with the training process, if the physical does not support the athlete's performance then the athlete will not be able to display maximum technical, tactical and mental abilities (Zhannisa & Sugiyanto, 2015).

A person's physical quality is supported by various physical components of the body, including strength, aerobic endurance, flexibility, and speed development (Bompa & Carrera, 2015). However, among all of this, the strength component is the basis for other physical components, such as speed, endurance, agility, and of course, power generation (Marshal, 2009). Therefore, the strength element in this sport must continue to be trained, where the main goal is to improve performance and reduce the risk of injury (Nour-Frías et al., 2024). Strength is the biomotor component that has the greatest influence on the biomotor abilities of speed, endurance and coordination (Peper et al., 2008; Suchomel et al., 2016). Various professionals in strength training, including athletes, physical trainers, coaches, physical education teachers, use physical exercise (González et al., 2022). Healthy participants and athletes can improve sprint time and strength with combined strength training (Muñoz et al., 2024), and an athlete's ability can be seen by carrying out a performance test, which is a collection of measurements used in sports science and coaching science to identify a person's physical fitness, health condition, or sport-specific abilities (Currell & Jeukendrup, 2008; Robertson dkk., 2014).

One element of strength in the body is abdominal muscle strength. Abdominal muscle strength has an important role in human life in increasing stability in physical activity (Blazek et al., 2019; Hackett & Chow, 2013). With regard to the muscles of the trunk, any training of the abdominal muscles seems to be very important. Although the abdominal muscles are significantly weaker than the back muscles, their importance for achieving adequate trunk stability cannot be denied (Christoph et al., 2020). One movement to train your abdominal muscles and also determine the quality of your abdominal muscles is sit ups. Sit Ups are a very simple movement that can be done anywhere, commonly done by people for routine exercise with the aim of increasing the endurance of the abdominal muscles (Childs et al., 2009), The movement is very easy, namely in a lying position with your fingers holding the back of your head, try to get up and bring your elbows together with your knees (Bianco et al., 2015). This movement is related to flexion, torsion and retroflexion of the trunk which is not only important for athletes, but also the general public (Noguchi et al., 2013). Apart from that, sit ups are often used to measure the strength of the abdominal muscles (Hoeger & Hoeger, 2016; Kukić et al., 2022; Lin et al., 2021; Lopes Dos Santos et al., 2023).

It seems that most abdominal muscle strength measurements still use manual and conventional methods, namely participants doing sit ups and someone recording the results. In these tests and measurements, the assessment is often not objective, there are times when participants make incorrect movements, but the results are recorded as correct movements, even though the test results are important to support the development of sports performance (Dhevangga Pristawan Abhimasta, Stanislause Wiriawan, 2020). As happened in South Sumatra Province in various physical tests and measurements such as: physical tests for South Sumatra PELATDA PON athletes, physical tests for acceptance and monitoring of South Sumatra PPLP athletes, physical tests for new student admissions at the Sriwijaya State Sports School in the abdominal muscle strength test component which is still carried out with the sit up test conventional or without tools. This seems to be a problem in the development of sports science, where on the other hand, many developed countries have used technology as a measuring tool for sports tests, but on the other hand, especially in countries that are still developing, this technological progress must be a serious concern. Therefore, now there is a need for a form of sports testing and measurement that is technology-based.

Creating technology-based tests in the sports sector is an innovation and will be better and tend to be more objective (Susiono et al., 2024; Usra et al., 2024). Many information technology-based services have evolved as cellphones have become more powerful (Abdillah & Kurniasti, 2022). As smartphone technology develops, it is currently developing rapidly and is divided into various operating systems such as iOS, Windows Phone and Android. However, in Indonesia the dominant technology products are Android-based devices (Agustina & Wahyudi, 2015). In the current era of the Alpha Age, technological progress is progressing very rapidly, as is technological progress in the field of sports, especially in test instruments. Some research related to sit up tests includes: developing an Android physical fitness test application to calculate the results of tests that have been carried out manually such as (push up, sit up, pull up tests, etc.) (Aditya Gumantan, 2020). Tools for sit up tests using Arduino (Efendi, 2021) sensors (Kurniawan, 2021). Developing a digital sit up test application (Mardela et al., 2023) android application for Arduino and ultrasonic based sit up tests (Rifki et al., 2022). The latest in my research is that this tool can calculate correct sit up movements along with their categories, calculate incorrect movements and have an automatic timer and the results can be downloaded via the Android application. The development of a Kinect camera-based sit up test instrument can provide benefits in measuring the performance and quality of sit up movements. Kinect can be used to measure kinematic and spatial parameters of body movement with acceptable accuracy (Geerse et al., 2015). In addition, Kinect can be used to detect body postures such as sitting and standing (Yang & Chuang, 2013). This study aims to develop a sit-up test instrument using a Kinect camera to accurately measure performance and evaluate the quality of sit-up movements.

2. METHODS

2.1. Design and Participants

This research uses a Research and Development research design, using a 4-D model, which consists of at least 4 implementation stages, that is: Define – Design – Develop – Disseminate (Çubukçu et al., 2020).

A total of 15 people were tested in small groups and 40 people were tested in large groups to participate in this study. The subjects of this research were male athletes aged 15–22 years, consists of several types of sports, namely Rowing, Diving, Volleyball, Football, Table Tennis and Sepak Takraw, with an average height of ± 177.8 cm, an average body weight of ± 67.9 kg. The subjects had previously agreed and were willing to be involved in collecting data for this research. Based on the research objectives, the subjects involved will be required to carry out sit-up movements according to the applicable test, where the movements can be described as follows: The instrument for testing abdominal muscle strength is the sit-up test, this test is carried out in the following way : (1) Testi lie on your back, (2) bend your knees until they make the smallest possible angle, (3) interlock your fingers, place them behind your head , (4) feet placed on the floor or mattress a few inches apart, (5) back and arms must touch the floor or mattress, (6) do the movement to get up, then return to the original position, (7) before getting up the back and arms must touch the floor (Ismaryati, 2011 ; Nurhasan, 2000; Widiastuti, 2017).

2.2 Instrument and Procedure

Based on the research objectives, the subjects involved were required to carry out sit-up movements according to the applicable test, where the movements can be described as follows: The instrument for testing abdominal muscle strength is the sit-up test, this test is carried out in the following way: (1) Testi lie on your back, (2) bend your knees until they make the smallest possible angle, (3) interlock your fingers, place them behind your head, (4) feet placed on the floor or mattress a few inches apart, (5) back and arms must touch the floor or mattress, (6) do the movement to get up, then return to the original position, (7) before getting up the back and arms must touch the floor (Ismaryati, 2011 ; Nurhasan, 2000; Widiastuti, 2017).

At the development stage, expert testing is carried out using research subjects that have been explained in the participant section. This research involved 3 experts who are competent in their fields, namely sports test and measurement experts, sports biomechanics experts and software experts who aim to determine the validity, practicality and effectiveness of the products that have been designed. Sports test and measurement experts assess the suitability between the type of test and the criteria obtained, while sports biomechanics experts look at every movement made by the participant, which ones are correct and which ones are incorrect, and software experts are tasked with looking at practicality, suitability and also the functionality of the product being developed, in this case the "Muscle Endurance Test" application software with the application on the "Kinect Measurement" operator. This design is based on research Llerena et al. (2020) that for product development it is best to use instrument validity testing using expert judgment techniques. After carrying out the validity testing stage, the resulting product will be tested for reliability testing.

2.3 Assessment Criteria Guidelines

The experts use the assessment criteria guidelines from the Deputy for Sports Achievement Improvement, Assistant Deputy for the Application of Sports Science and Technology, Ministry of Youth and Sports of the Republic of Indonesia which can be seen in the expert/expert assessment criteria table (Table 1).

Table 1. Expert assessment criteria

No,	Criteria	Assessment Indicators	Weight
1	Aspect of Originality	This is the result of the work of researchers.	10
		Has differentiating features compared to existing similar sports technologies (originality).	10
2	Aspects of Innovation Excellence	Has advantages in terms of quality of innovative work, materials, operation and maintenance.	10
3	Benefit Aspect	Has high efficiency for institutions in supporting sports development efforts.	20
4	Economic aspect	Has a positive impact from the application of technology and industrialization, giving rise to other industries (Multiplayer Effect).	10
		Has commercialization potential and market reach.	10
5	Security aspect	Has a good level of safety when used by athletes and students.	10
6	Convenience aspect	Has a good level of comfort when used by athletes and students.	10
7	Aspects of completeness of supporting data	Has a description of the usage manual	10
		Amount	**100**

Source: *Deputy for Improving Sports Achievement, Assistant Deputy for Application of Sports Science and Technology, Ministry of Youth and Sports of the Republic of Indonesia;*
Note: *the assessment range uses a scale of 1 – 100; 81 – 100 = Very good; 66 – 80 = Good; 56 – 65 = Fair; 41 – 55 = Less; 0 – 40 = Very poor*

Cronbach's alpha was utilized as the reliability test, with a minimum value of 0.6 (Taber, 2018) necessary for reliability.

3. RESULTS

3.1. Tool Working System

1) This tool consists of an Android application that has been created and named "muscle endurance test" which can be downloaded on Playstore: https://play.google.com/store/apps/details?id=com.binus.aplikasikebugaran&hl=in&pli=1. This application is used by test participants and test officers, the Kinect camera and the "Kinect measurement" operator application as a link between the Kinect camera and the Android application, 2) Participants download the Android application "muscle endurance test" by filling in their biodata in the application (can be done anytime and anywhere before the test), 3) During the exam, the exam officer calls the examinee to confirm the biodata that has been filled in on the Android application. This is done to connect the Android application and the "Kinect Measurement" operator application

using the test participant's cellphone number which has been entered in the Android application, 4) When the Android application and the "Kinect measurement" operator application are connected, the test officer directs the test taker to carry out the test. The implementation of this test is still guided by the test officer. However, the calculations are automatically calculated by a Kinect camera which has been developed into a "Kinect measurement" operator application. The test results are immediately sent to the Android application "muscle endurance test", 5) This test must be carried out indoors, so that the Kinect camera is more accurate in capturing movement, and 6) Carrying out this test must use the internet and electricity. The internet functions to connect the "muscle endurance test" application with the "kinect measurement" operator application and automatically transfer test results from the "kinect measurement" operator application to the "muscle endurance test" android application, while electricity is needed to turn on the Kinect camera. For more details on the implementation of data collection and the research process carried out using Kinect camera observations, you can see the following image:

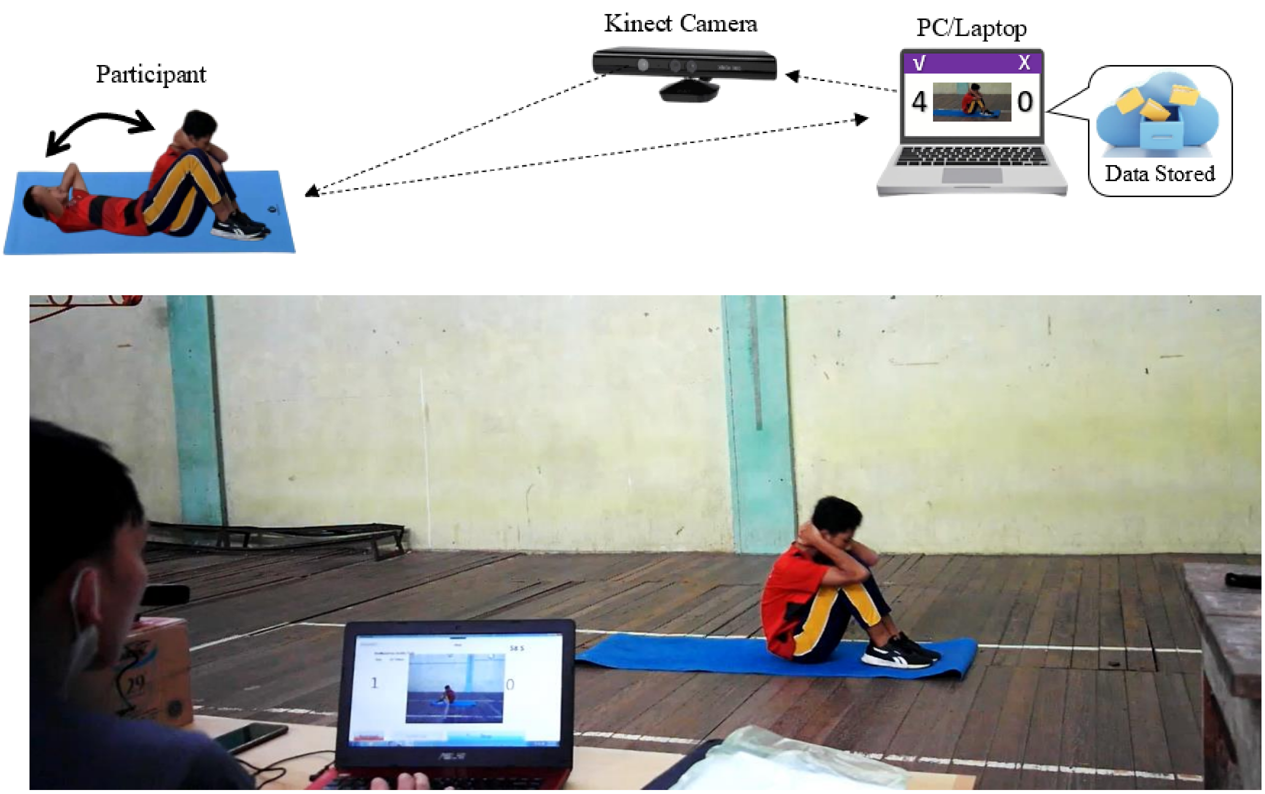

Figure 1. Data collection process

The working function of the test instrument that I developed is: 1) Can easily detect and count correct and incorrect movements from the sit up test, 2) Makes different sounds to indicate correct movements and incorrect movements, 3) there is an automatic timer that runs postponed as the deadline for carrying out the test, 4) Sit up movements and calculations can be monitored directly on the laptop, 5) Test results & categories are automatically sent to the testee via the "muscle endurance test" application after the timer runs out. The test results and categories are saved in their account and can be downloaded as a pdf.

3.2. Validity

From the results of the assessment, the sports test and measurement expert received a score of 81, the sports biomechanics expert 87 and the software expert 86. Of these three experts, the assessment results can be categorized as very good. The assessment results can be seen in the table below (Table 2).

Table 2. Expert assessment results

No	Criteria	Assessment Indicators	Sports Test and Measurement Expert	Sports Biomechanics Expert	Software Expert
1	Aspect of Originality	This is the result of the work of researchers.	9	10	9
		Has differentiating features compared to existing similar sports technologies (originality).	8	10	9
2	Aspects of Innovation Excellence	Has advantages in terms of quality of innovative work, materials, operation and maintenance.	8	10	9
3	Benefit Aspect	Has high efficiency for institutions in supporting sports development efforts.	15	18	17
4	Economic aspect	Has a positive impact from the application of technology and industrialization, giving rise to other industries (Multiplayer Effect).	8	7	8
		Has commercialization potential and market reach.	7	8	8
5	Security aspect	Has a good level of safety when used by athletes and students.	10	9	10
6	Convenience aspect	Has a good level of comfort when used by athletes and students.	10	10	10
7	Aspects of completeness of supporting data	Has a description of the usage manual	6	5	6
Amount			**81**	**87**	**86**

3.3. Reliability

The item reliability criteria are evaluated based on item reliability and Cronbach's alpha (α). The item reliability values range from 0.98 to 1.00 for all items in the Kinect camera-based sit-up test instrument confirming the reliability achieved. The Cronbach's alpha (α) values are 0.82 and 0.78, which exceed the minimum value of 0.6 (Taber, 2018) required for reliability. The results confirm that the Kinect camera-based sit-up test instrument is a reliable measure (Table 3).

Table 3. Data reliability testing results

Criteria	**Aspect**						
	Originality	**Advantage**	**Expedience**	**Economy**	**Safety**	**Comfort**	**Supporting data completeness**
Number of Items	2	1	1	2	1	1	1
Mean	9.33	9	16.67	7.67	9.67	10	5.67
Cronbach's Alpha	0.98						

4. DISCUSSION

The research results showed very good validity and reliability values. This was also proven during the data collection process, where the Kinect camera was able to read every movement made by the participant. Every correct and incorrect movement can also be read by the system, which of course is based on the results of testing by biomechanics experts. Kinect is an input device for detecting movement produced by Microsoft for the XBOX 360 Video Game and PC with the Windows operating system (Raditya & Irawati, 2015). Kinect cameras were first developed as exergaming devices, Kinect V1 and V2 were adapted to quantitatively study human movement in various activities (Ripic et al., 2022), and it is also suitable for dynamically reading measurements of human body posture (Eltoukhy et al., 2017). Kinect is equipped with an RGB camera, Depth Sensor, Multi-Array Microphone to capture and recognize sound, and is equipped with a Tilt motor to adjust the degree of camera capture. Kinect Depth Sensor technology is a three-dimensional (3D) sensor for recognizing player movements (Wanangsyah et al., 2014). The Depth Sensor consists of an Infra-Red (IR) projector combined with a CMOS monochrome sensor. This is what can make Kinect see in 3D in any light conditions. Calculations of the distance between objects captured with Kinect are obtained based on infrared rays. The shorter the distance, the brighter the points captured by the sensor (Reynolds et al., 2014).

Using a Kinect camera also helps users analyze every movement, from simple to complex movements (Fikri et al., 2022). Kinect can measure step length, step time and relevant step width during walking on the ground (Abbasi et al., 2021; Guess et al., 2022). Research Thomas et al. (2022) which was developed to measure movement in the sit-to-stand test (STS), the results showed that Kinect was capable of accurate, and clinically relevant, assessment of movement data when performing STS. Can measure the potential of the body's joints in carrying out physical activities (Woldegiorgis et al., 2021). Analyzing the validity and reliability for shoulder movements, the results were valid and had excellent intra-rater reliability for shoulder abduction, flexion, external rotation, internal rotation poses (Çubukçu et al., 2020). Kinect cameras are recommended for studying human skeletal information captured by Kinect sensors (Li & Li, 2020). The Kinect v2 sensor provides a valid and reliable measurement of hip, knee and ankle joint movement (Oh et al., 2018). The results of his research (Banky et al., 2019) using Microsoft Kinnect showed that Microsoft Kinect had excellent capabilities for measuring ROM (Range Of Motion) during flexibility assessments, in fact this tool was superior in measuring the initial and final angles of human joints. Kinect with its camera auto-tracking capabilities makes it potential for sports biomechanics and motion analysis. (Choppin & Wheat, 2013). A depth sensor-based motion analysis system with fast and portable capabilities (Özsoy et al., 2022). Microsoft Kinect v2 provides color (1920x1080 @30Hz) and infrared (512x424 @30Hz) data streams, depth images (512x424 @30Hz), body index images (512x424 @30Hz) and skeletal information for each detected person (25 joints @30Hz). The tracking volume sensor is determined by the field of view from the front of the camera at a distance of 0.5 – 4.5 meters (Müller et al., 2017).

Human movement capture is implemented using the Kinect IR Emitter sensor which emits infrared rays, which reflect from the object to be detected by the IR Depth sensor (Iliukhin et al., 2017). Relying on motion analysis to measure angles and distances, it is used as a score to assess the quality of posture, which allows it to perform human body tracking to retrieve the 3D position and orientation of 25 joints (Bittar et al., 2017). This is in line with the infrared emitter and depth sensor of the Kinect can detect the contours of the human body and identify 25 joints in 3-D space with high precision (Xu & McGorry, 2015).

5. CONCLUSIONS

The Kinect camera-based sit-up test instrument was found to be effective and efficient to use, with results that are valid and reliable in the very good category. However, a limitation of this tool is that it cannot be used outdoors, as the Kinect camera is not optimal for capturing movements under sunlight. Therefore, the recommendation from this research is that if you want to use a Kinect camera to measure movement skills, it should be done indoors.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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