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The biomechanics form and ıts application to assess student's physical skills

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Abstract

One of the intended learning outcomes of Physical Education (PE) is for students to develop physical skills. Biomechanics can be used as a discipline to measure the level of physical skill. This study aimed to develop an assessment form to measure the level of physical skill. The movement principle of biomechanics was incorporated into an observation checklist form. The form is meant to help Physical Education Teachers (PET) qualitatively analyze students' physical skills using biomechanics. This study aligns with research and development model which conducted in three phases: need-analysis, development, and model efficiency test. The form was built with two main components: physical skill and biomechanical principles. Physical skill is related to standard movement patterns for a given sporting skill. The biomechanical principle lays the foundation for all movements. This research uses a qualitative approach. A total of 120 PET from 120 secondary schools were involved as subjects in this study. Interviews, observation, and questionnaire were used to collect the data. This research yielded the following result, first, there are problems with integrating biomechanics into an assessment of physical skill. Second, a biomechanics form is developed in the checklist-style observation form to help PET evaluate their students' learning outcomes. Third, biomechanics form was practical to be used as a learning assessment tool because it met the criteria of validity, practicality, and effectiveness.

Keywords: biomechanics assessment; observation checklist; physical education, physical skills

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1. Introduction

Physical Education (PE) has been added to the national education curriculum for the last few decades. Many believe PE serves a central role in helping children achieve the ultimate educational goals, which are enjoying the learning process, making progress, and achieving the learning goals. Students are also expected to grow into confident individuals who can live safe, healthy, and fulfilling lives. Finally, students are encouraged to become responsible citizens who positively contribute to society (Capel & Whitehead, 2010). PE has been added to the two national laws within two ministry jurisdictions in Indonesia. The Indonesia Ministry of Education and Culture stated in the Law Number 20 of 2003 that PE is essential to the national primary and secondary education curriculum. PE is one of the instruments to accomplish targets of education. Education in schools facilitates students to develop themselves as fully competent individuals who are intelligent, diciplined and demonstrate good character (Djumali & Wijayanti, 2018; Prasetyarini et al., 2021; Prayitno et al., 2022). The issue of education is even more crucial amid globalization era which creates disruptive lifestyle. Education is important to prepare student to adapt to global challenges and improve their quality of life (Ishartono et al., 2022). Any types of education in school, including physical education need to elaborate the goal of education to benefit student as a lifelong learner. The Indonesia Ministry of Youth and Sport on Law Number 11 of 2022 defines PE as a structured and continuous effort within the education system to enhance the student capability to live safely, happily, and enjoy good health throughout their life. Kretchmar (2006) highlighted the following benefits students could access from PE (1) helps prevent illness; (2) promoting happiness, self-esteem, and general well-being; (3) helping to tackle obesity; (4) promoting physical fitness throughout life, (5) increase the probability of activity persistence; (6) providing management and movement skill that related to health; (7) not detracting from academic goals and have more opportunity to improve them; (8) make student economically rational; and (9) fostering whole-child education. Others believe that being active in physical activity could improve quality of life, physically and mentally (Eddolls et al., 2018). Given the numerous advantages of PE for student personal development, teachers are expected to design work and teaching approach to help students achieve the benefits of PE.

Students' personal development can be classified into five different aspects: health and physical, way of life, social, emotional, and cognitive (Bailey, 2006). However, one that distinguishes PE significantly from other subjects is development in the physical domain. PE in schools allows students to exercise on a regular basis, making it an effective means of developing students' physical skills (Sallis et al., 1997). For most student, school is the most suitable environment for physical activity, through PE as a curriculum program or extra-curricular program (Telama et al., 1997). PE improves students' physical skills by teaching them basic physical skills. Students in PE class are required to perform physical tasks that lay basis to basic movement ability associated with commitment to an active and healthy lifestyle, both during childhood and later in life (Okely et al., 2001). There is also a hypothesis that children with outstanding physical skills will likely achieve sporting excellence (Bailey, 2006). Therefore, physical education teacher (PET) should prioritize delivering knowledge about fundamental movement skills through demonstration, class activity, and student performance evaluation.

PET can evaluate students by assessing them during lessons or at the end of teaching and learning. Ideally, teachers conduct observation over the student activity, judging their movement, and observe the children, analyze their movement, and plan whether to adjust the task, present a cue, introduce a challenge, or sending feedback (Bailey, 2006). A teacher must be a good observer to make the teaching even more effective. Observation is beyond watching, it requires systematic preparation and decent movement knowledge, awareness and focus to individuals, small or large groups, recording and reporting plans; and an initiative to practice this information to increase teaching quality.

PETs need to develop themselves to become perceptive observers of human movement. To acquire such ability, they must understand that biomechanics provides a scientific basis for every movement. Biomechanics

evolves as a scientific discipline in sports and exercise science. Biomechanics is critical in elite sports for developing potential athletes by improving athletic performance, preventing injury, and hastening recovery. A good knowledge of movement can be understood if teachers recognize basic movement principles by studying and implementing biomechanics into their analysis when observing students' physical skill. Through movement principles, teachers can understand 'the anatomy of movement' and the makeup of movement skills. Donnelly & Gallahue (2017) called this as movement principles or concepts that define "a specific language of movement." This language enables PET to observe and describe movement in a broader and fuller way. However, only limited studies have focused on learning biomechanical concepts to elaborate with teaching strategies (Knudson, 2010).

Biomechanics is important for PET. There is general agreement that biomechanics should remain in the undergraduate curriculum (Hamill, 2007). However, biomechanics theories are rather rarely used by teachers in their daily professional task. According to Ladeira et al. (2011), nowadays prominent coaches are more likely to use biomechanical theory into their practice rather than teacher in their PE lesson. Belmont & Lemos (2016) reviewed and highlighted the causes of factors that constraint the application of biomechanical content by PE teachers into the following (1) teacher feels difficult to understand biomechanical textbook (2) biomechanical research mostly dealing with non-pedagogies issue that make teacher unable to relate them into their daily practice, and (3) biomechanics introductory course do not foster the application of biomechanical concept and its application on pedagogies setting.

Based on the above phenomenon, the application of biomechanics in pedagogical settings is necessary to improve physical skill analysis during teacher observation of their students. Therefore, accurate analysis of physical skills can help improve student learning performance. One of the strategies to make accurate judgments on students is through the development of observation forms that consist of a special language of movement. The form is designed to enable PET to monitor physical skill, analyze it, and provide feedback to improve student performance. Only by having accurate judgment through the use of an appropriate instrument, teacher can establish strategies and ability to improve student learning in PE (Gaumer Erickson et al., 2017). To achieve the mentioned ideal on assessment, this article has the following purposes: first, it aims to develop an observation form based on biomechanics as a special language of movement. PET can use the form to determine the quality of students' physical skills. Second, it aims to study the effectiveness of the biomechanics form in practical application.

2. Methods and Materials:

This study uses research and development to create an instrument for physical skill assessment. This study was conducted using a mixed-methods design. The Borg and Gall (2003) research approach was selected over a systematic process and its dominant practice in research and development (R&D) area. Research stages include need analysis, product design, product testing, product revision, and product installation. A preliminary study was conducted to investigate what physical tasks needed to be addressed in the observation form. The preliminary study was conducted using interviews, literature studies, and observation methods. The result of the preliminary study was used to determine the product design that would meet the demand in the professional field. Six PET were recruited as participants in the need analysis study to determine physical skill needs to be addressed in the assessment form. The study chose the underhand passing of volleyball as the physical skill to be analyzed in this study. This made sense because volleyball has a major part of the physical education curriculum in secondary school. This study develops an observation form that can be used to analyze the students' underhand passing ability. Literature studies on volleyball and biomechanics were used as a theoretical framework to develop the instrument, which met construct validity. The nine-movement principle of Knudson (2007), including balance, inertia, force-time, optimal projection, and spin, was adopted in the instrument. The design stage was collaborative and participatory, involving experts in volleyball, pedagogy, and biomechanics. Content validation was delivered through expert judgment of an instrument

that explores the description of movement and matches it with related biomechanical principles. Experts in volleyball, biomechanics, and pedagogy were recruited in content validity analysis. The instrument's content was mainly a combination of movement description and the nine-movement principle in biomechanics.

A limited trial on a newly designed observation form was conducted to test the product's feasibility. Among the PET students in secondary schools in Central Java, 25 were selected to participate in an online questionnaire aimed at collecting experience and feedback toward improvement of the instrument. Out of 25 subjects, five were selected for further response analysis using a semi-structured interview. Expert consultation was held to revise the product according to responses from subjects. Finally, the revised product is ready for large scale implementation. A total of 90 PET have participated in product implementation. They were instructed to apply biomechanics to measure student skill in underhand passes. After completing the Biomechanics form, participants' responses were calculated using a 5-point Likert scale (1-strongly disagree to 5-totally agree). In addition, a semi-structured interview was conducted to confirm the results from the questionnaire. Ten PETs were chosen from a pool of 90 to participate in the interviews. The effectiveness of the biomechanics form in measuring physical skill was concluded from the elaboration of the questionnaire and interview results. Quantitative data result from a questionnaire presented using descriptive analysis. Qualitative data resulting from interviews were analyzed using narrative analysis. The Universitas Muhammadiyah Surakarta research advisory board cleared this study from ethical issues. All respondents were informed about the research before conducting the data collection. All subjects in this study have submitted informed consent to indicate their agreement to be involved in this study.

3. Results /Findings

The current practice of physical skills assessment in secondary school

The interviews and the forum discussion group data reveal the current assessment practice for movement competence in high school physical education classes. The unprecedented COVID-19 pandemic has forced schools to diminish face-to-face teaching in school. Students were instructed to access their education from home to avoid contact with the virus. This caused major disruption to the education system, including physical education. Majority of global students or nearly 94% of the student's population worldwide had been affected by the closure of education facility and learning places (Pokhrel & Chhetri, 2021). This has forced the education system to adopt changes in all aspects of the system. Physical education is no exception in that case. Many teaching strategies have been adapted to Massive Open Online Courses (MOOCs) to substitute face-to-face teaching. However, PE teachers in high school still finds it challenging to optimize the learning experience for their students using MOOCs. Several problems arise regarding this matter, including the limited ICT literacy of students and teachers, the limited internet access, and communication devices. Ineffective learning frequently leads to burnout, a situation in which students lose motivation for learning, which can lead to a drop in academic performance. Burnout, according to Robins (2018), is a psychological syndrome associated with prolonged stress on a professional task, and it is characterized by three components: exhaustion, cynicism, and low professional efficacy. Studies show that teachers play a critical role in improving student motivation. Teachers are encouraged to adopt a new teaching style, using creative and exciting learning sources, and show their support to the students throughout the academic activity (Bartholomew et al., 2018; Hagopian & Nohria, 2021; Iswardhani & Djukri, 2015; Liu et al., 2021).

The assessment conditions in this study can be broken down into two eras, which are the pre-COVID-19 era and the post-COVID-19 era. The pre-COVID-19 era refers to the period preceding the covid-19 pandemic, while the post-covid-19 era refers to the period following the covid-19 pandemic. In pre-COVID-19 era, students were evaluated based on their performance during teacher observation of class activities. Students were provided with feedback to improve their learning. To assess student performance in PE, both formative and summative assessments were used. Formative assessment was meant to look forward, while summative assessment was meant to reflect on student physical activity. During the pre-COVID-19 era, teachers had full

access to their students since class was held offline. It is the teacher's daily task to observe their students, and decide whether to adjust the task, present a cue, introduce a challenge, or sending feedback. Given observation as the assessment method, teachers understand that observing the student is more than just keep an eye on their movement, it requires systematic preparation and decent movement knowledge. The fact that there is autonomy for PE teacher to grade their student in Indonesian secondary schools, teachers are likely teaching their students sports under the teacher's expertise. Therefore, teachers are not difficult to assess because they have a strong foundation of movement knowledge. During this time, teachers were satisfied with their assessment practices, especially concerning the movement analysis of their students during assessment.

Contrary to the pre-COVID-19 condition, during the COVID-19 pandemic, teachers admitted that they had lower standards when they graded students' work. The COVID-19 pandemic has driven far reaching adjustment and unmatched realities for teacher and student in term of practicing PE in schools (Howley, 2021). Many problems in education arise because face-to-face learning is temporarily being replaced with online learning. Several issues were raised during the interview, including low student participation in doing homework, limited access to gadgets and the internet, inadequate teacher supervision of the student's activity, and an overwhelming schoolwork burden from another subject. They also admitted that teachers had trouble incorporating their learning into online platforms.

In some cases, this is due to a lack of Information and Communication Technology (ICT) literacy. The results of Centeio's (2021) research revealed that overcoming and learning technology was one of teachers' success during COVID-19 pandemic. Teachers were unprepared to concurrently build pedagogical and content knowledge with technological knowledge during this unprecedented online learning event. Leave alone COVID-19 pandemic, in modern times teachers are required to have ICT capabilities into their competencies (König et al., 2020; Segal & Heath, 2020). Education has been rigorously affected by the COVID-19 pandemic due to both teachers' and students' difficulties adapting to the new situation (Anugrahana, 2020; Azzahra, 2020; Flores & Swennen, 2020; Howley, 2021; Sandars et al., 2020).

The development of biomechanics form as an instrument to assess students' physical skill in underhand passing of volleyball

SWOT analysis, study of literature, and focus group discussion from PE teachers all contributed to the development of the biomechanics assessment instrument. Knudson (2013) describes qualitative biomechanical analysis as organized observation and mindful judgment on the level of human movement to deliver the most suitable intervention to enhance performance, effectivity, and safety. In this study researcher decided to make volleyball's underhand pass an object of analysis. This comes from the fact that this movement is part of most junior and senior high school PE programs. The development of a biomechanical-based observation checklist to assess students' underhand passing skill is as follows. First, the using instruction was created at the beginning of the checklist. The instruction enables the reader to understand the purpose of the checklist and how to use it better. Second, the movement skill being assessed is depicted in the illustration. The illustration explains the movement phase and gives the perspective of the ideal movement image to the rater (See appendix 1). There was a revision after a limited trial as some viewed the image being displayed as not clearly representing the whole movement phase. Therefore, the image on the final product was upgraded into a time-lapse movement picture. Third, the early design of the model of movement skills assessment based on biomechanical principles is progressed into a checklist table that comprises several following components, (1) strategic goal of the movement, (2) mechanical goal of the movement, (3) description of each phase of the movement (preparatory, execution, follow-through), (4) body segment illustration, (5) score and checklist box, and (6) comments.

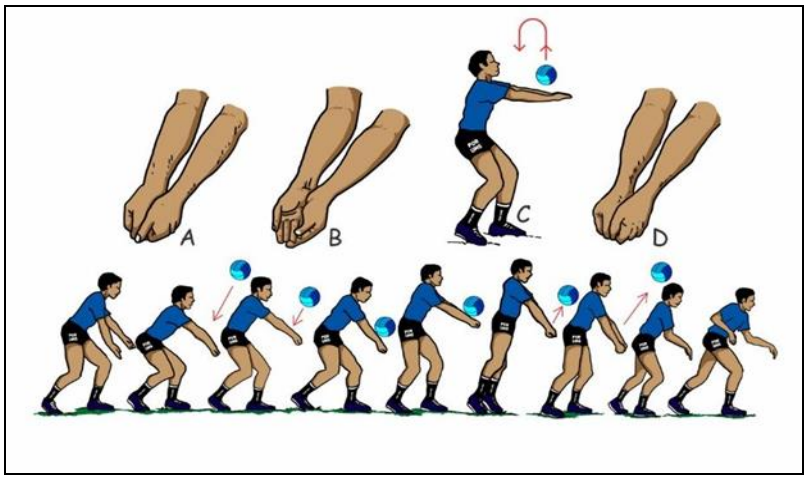

Figure 1: Time-Lapse Illustration of Volleyball's Underhand Pass

Strategic goal of the movement

The goal of a movement is its intended outcome. With a specified goal in mind, the performance can be evaluated to determine whether the goal is reached. The goal of the underhand pass is to get the ball toward the target. A good pass is characterized by the ball accuracy, meaning that regardless of the distance between the passer and the target, the ball will go and hit the target player. Therefore, in the checklist, the strategic goal of the movement is whenever the ball can be easily caught by the target player. The design of this observation checklist was brought to the expert panelist, which consisted of academics and practitioners in volleyball, physical education, and biomechanics, for validation checking. There was no correction regarding the stated strategic goal of the movement of underhand pass.

The mechanical goal of the movement

Movement in sport is comprised of a product and process. The above description of strategic goal is essentially a product of movement. Meanwhile, the mechanical goal can be considered the process of movement. In movement, force is the cause and motion is the effect. Any feedback during movement analysis should be directed to the cause of the movement. When movement results in the desired outcome, it is a good process. The mechanical goal for every movement is to use the body's locomotor system to activate skeletal muscle and produce an impulse that is applied to the body to be moved. The applied impulse must match the amount of momentum required to attain the strategic goal. The equation of impulse is Ft or force applied for time. The concept of application of impulse should bring to light possible sources of a problem with performance, such as the following error possibilities (1) the amount of force applied: the magnitude of the external force can be too much or too little, causing a dissatisfying performance; (2) The direction of the applied force: the external force can be applied in the opposite direction of the intended momentum, resulting in poor performance; (3) The duration, or time, of force appliance: The external force can be applied for too short or too long a time, causing a dissatisfying performance. Successful performance depends on applying the optimal impulse in the correct direction. Any combination of errors in size, direction, or duration of force application creates an incorrect impulse and causes incorrect momentum and dissatisfying performance.

In terms of the mechanical goal of an underhand pass, on the observation checklist, it has been described as a muscle's stretch-shortening cycle (SSC) happening on the arm and leg. The SSC is defined as the muscle ability to stretch immediately followed by muscle action to shorten its length. This is similar to spring mechanism. On the preparatory phase, the muscle begins the stretch cycle by activating eccentric contraction. By doing this, athletes can produce more force and move quicker. Usually during the preparatory phase, the body segment is

brought backward and downward; therefore, this phase can also be called countermovement phase. On an underhand pass, arms are brought backward, and legs are brought downward.

During the execution phase, arms are brought forward, and legs are brought upward to create the external force needed to hit the ball. The mechanic principles that apply to this situation are coordination continuum and segmental interaction. Because the underhand pass required little force and quick movement, serial muscle and joint movements are advantageous to the results of motion. Whereas the principle of segmental interaction is necessary to produce the needed force using the kinematic chain between the legs, body, and arm.

Follow-through is the final phase of the movement, which experts regard as a symptom of good movement rather than directly affecting the movement itself. During follow-through, the body is experiencing deceleration before eventually coming to a stop. It is easy to analyze the movement if the rater knows how the movement should end. On the observation list, there is a checklist to record the visual and give a checklist on scorebox if the performer meets the described criteria.

Score and checklist box

Upon retrieving visual information through observation, the rater was expected to judge the movement by its strategic goal accomplishment. The achievement of a strategic goal received the majority score on the observation checklist. However, the analysis should not end if the performer meets the strategic goal of the movement. There is still room for optimization in such a case. As a result, the analysis continues with the mechanical goal of the movement in order to determine the cause of the performance. The rater is directed to finish the checklist available for every movement phase for everybody segment. There are four body segments in the analysis, including the head, arm, body, and leg. The rater should focus on those for the body's segment as the body moves sequentially from the preparatory phase to the execution phase and then to the follow-through phase. There are characteristics of everybody segment across the phases. The rater should give the available score whenever the performer's body segment meets the movement phase characteristic.

Table 1: Scoring guidelines

Parameter	Object	Score allocation (Total score=100)
Strategic goal	Result of the movement (ball projected straight)	40
Mechanical goal (*preparatory phase*)	Head, arms, body, legs	20
Mechanical goal (*execution phase*)	Head, arms, body, legs	20
Mechanical goal (*follow-through phase*)	Head, arms, body, legs	20

The effectiveness of a biomechanics assessment instrument to determine the level of student's movement skill quality

The results of the biomechanics assessment instrument's effectiveness in determining the level of a student's movement skill are related to the validity, practicability, and effectiveness standards proposed by Nieveen (1999). The fundamental aspect is the issue of validity of the biomechanics assessment instrument to analyze the movement of the student, which in this case is volleyball's underhand pass. (1) If minimum two of the three validators conclude that the model is having a strong theoretical basis, (2) If minimum two of the three validators conclude that the model is showing interrelation to each other consistently, (3) based on the test

result, if components in the model is interrelated, the model is classified as valid. The initial draft of a biomechanics assessment instrument in the form of an observation checklist fulfill the requirements of a strong theoretical foundation and the interconnectedness of components in the assessment model, according to the results of expert judgement during the validity test on limited trial phases.

The second aspect is about a practicality of the biomechanics assessment instrument. The assessment model categorized as practical due to the following aspects: (1) Minimum two of the three validator consider that the assessment form can be applied in the classroom(2) From the perspective of user, most teacher involved in this study is able to use this form in their professional task to grade student; and (3) the assessment model's level of application is significant. This study recruited validator that come from practitioner (volleyball coach and PE teacher specializing in volleyball) to validate the model on limited trial phase. They believe that the assessment model is valid to measure ability to do underhand pass. Furthermore, they consider the feasibility of the model is high, meaning that the assessment model is applicable to be used in PE classroom. The final test result also indicated that many teachers perceived the observation checklist helpful in analyzing movement error and providing feedback based on biomechanics theoretical basis.

The findings of the limited trial revealed that observing teacher conduct accurately predicts criteria. The results of questionnaire analysis for the practicality indicator in an extensive trial show an average value above 4.2. According to Sugiyono (2014:135), a questionnaire value of 4.2 and above should be considered excellent. Since this requirement for the practicality of the observation checklist model was met, it was determined that the assessment model could be used in the classroom.

4. Discussion

Assessment practice on physical education class

Physical education has four goals that teachers are aware of: (1) develop physical skills; (2) expose every student to a variety of activities; (3) promote health and an active lifestyle; and (4) provide enjoyment for physical activity. Physical activity is not only provided to students in curricular program but also in extracurricular program in which students can participate in after school. However, during the pandemic, PE teaching and learning were carried out using an online learning platform. On the one hand, it offers flexibility on place and time of study. On the other hand, teachers and students perceived online teaching and learning activities to be inefficient. From the perspective of a teacher, online learning has increased their workload. This problem especially affects teachers without proper technological skills. This pandemic has forced teachers to shift their teaching to online platforms, some without adequate skill, making online teaching difficult. Technology has come with unprecedented challenges in teaching and learning. For teacher, challenges including keep on update with latest technology and make use of it to produce teaching content to catch most attention in today's modern student.

In terms of assessment, teachers understand that assessment is integral to teaching and learning. When discussing the fundamental quality of physical education, assessment is interrelated with curriculum and pedagogy (1). Assessment is necessary to give teachers information about the learning progress of their students. Teachers are demanded to identify student's strength and weakness in learning, fostering their strength to make it even better and identify possible way to correct their mistakes to make them improve further. According to Capel & Whitehead (2010:119–120), in education there are two distinctive types of assessment known as formative assessment and summative assessment. Formative assessment is conducted to monitor student progress in their learning, while summative assessment often uses in the end of the lesson to classify what student have been accomplished during lesson. Formative assessment mainly dealing with feedback. Teacher using formative assessment aim to identify mistakes and errors during lesson and provide informative feedback so student can improve themselves in learning, hence maximizing their potential by the end of the lesson. These two types of assessments can both be implemented in the class. However, experts

suggested that teachers be encouraged to utilize more formative assessment (Borghouts et al., 2017). This is given the trends showing that assessment in physical education has shifted from physical fitness to physical skill and knowledge (Chng & Lund, 2018). Therefore, assessment is needed to ensure the student's ability to master the skills and knowledge in PE.

The first phases of this study's findings discovered that teachers mostly concern themselves with the fact that assignments being administered to the students are not supposed to be perceived as a burden. The assignment was designed mainly to assess their engagement with the subject rather than to evaluate their skills and knowledge. Therefore, a student's work quality is no longer important if they are engaged with the class. This has become important as Borghout's (2017) finding exposed a difference between stated PE objectives and assessment practices. This is added to the problem of inadequate assessment in physical education over the last 40 years (Annerstedt & Larsson, 2010; Dinan Thompson & Penney, 2015; López-Pastor et al., 2013). In line with the findings of Borghouts's (2017) study, the results also confirmed that assessment quality needs to be improved to enable teachers and students to have enough information and knowledge to make valid judgments about the learning process and its outcomes. An adequate assessment tool is required to attain this goal. A good assessment should be both valid and reliable because the teacher is relying on it when giving feedback and running the diagnosis toward student performance after the assessment. Assessment validity and reliability can be perfected with the use of assessment criteria.

According to Borghouts (2017), observation is the most common method being used by PE teachers to grade their students. Capel & Whitehead (2010) added that observation is not merely looking but rather require good preparation and movement knowledge. Teachers need to be confident in observing a skill by ensuring they know about the observed activity. Teachers are expected to understand the basic elements of movement, often known as movement principles. Studies have supported the need for PE teachers to have adequate biomechanics knowledge (Hamill, 2007; Riskowski, 2015; Stiles & Katene, 2013). Donnelly (2017) refers to principles of movement or concepts as a special language to better understand movement. This language enables teachers to both observe and describe movement in a wider and fuller way. Based on the findings and reviews, physical education assessment practices should be combined with diverse movement principles added to assessment criteria for each step of competence that becomes the evaluation target. The main objective of skill assessment is not merely to judge the movement as good or bad; it should also provide feedback and cues based on the mechanical principle that students could use to improve their performance.

Design of the biomechanics assessment instrument

Through the form that has been created, teachers can assess the underhand service movements of their students. This form is easily applicable to learning because it uses simple terms and includes visual descriptions. It can even be used as an instrument by students to assess the movement skills of their peers. The outcomes of the development stages demonstrate the relevance of incorporating biomechanics into movement knowledge when evaluating and providing feedback on student skill performance. This is in line with Riskowski's (2015) research emphasizing biomechanics as a vital component in physical education. Biomechanics could support PE teachers to get to know the function of the locomotor system in movement tasks. Assessment in physical education can be carried out appropriately if teachers understand human movement principles as they relate to students' skill performance. Biomechanics as a subdiscipline of physics is relatively new in sports science. However, biomechanics has gained popularity in recent years because it simply serves as an effective approach to injury prevention and performance improvement in elite sports. Biomechanics has been adapted in various settings within sports and physical education. Movement analysis in biomechanics have been categorized as qualitative and quantitative analysis. Quantitative analysis includes the assessment of biomechanical variables and favorable to use of a computer to calculate the large numerical data. Even simple movements will need thousands of data samples to be obtained, scaled, and numerically analyzed. On the other hand, qualitative

analysis has more focus on systematic observation and introspective judgment of the profile of human movement to present the most effective intervention to enhance performance (Knudson, 2007).

Table 2. Ddefinition of 9 mechanics principle adopted in the observation checklist

No.	Mechanics Principle	Definition
1.	Force-motion	Object will remain at rest or still in motion until it experienced unbalance forces that disrupt their current movement status
2.	Force-time	The time duration of which the force implied to an object will increase magnitude of the force, hence it affects the resulting motion.
3.	Inertia	Objects have tendency to resisting changes in their current state of motion.
4.	Range of Motion	All motions in a movement can be categorized as linear or angular motion.
5.	Balance	Ability to keep the body position and line of gravity relative over base of support.
6.	Coordination Continuum	Classifying the optimal moment of muscle contraction and segmental action are closely depends on the objective of the movement. If the objective is to produce powerful movement to lifting maximum weight, muscle need to work simultaneously, while if the objective is to produce quick motion in highspeed condition, muscle and joint action need to work sequentially.
7.	Segmental Interaction	Moving body segment in sequence need coordinated action of muscle and joints. The force from one muscle to another can be transferred through joint as long as intersegmental movement happened continuously without a stop or pause.
8.	Optimal Projection	Every movement involving throwing or kicking object to mid-air, there is an effective range of projection angles that suits the specific movement goal.
9.	Spin	Rotations applied to a ball can determine its air trajectory.

In terms of its practical nature, qualitative biomechanical analysis can be applied to physical education, especially during assessment to measure students' skill performance. The purpose of the analysis is to help students reach a satisfying level of performance. In doing so, teachers are expected to carefully observe the movement, analyze, troubleshoot, and providing learning

feedback to their students. In general, quantitative, and qualitative analysis can be used independently when analyzing the movement. Quantitative analysis has advantages over qualitative analysis in terms of accuracy, consistency, and precision. Therefore, it is often used in many laboratory settings. However, the advantages come at a great cost because it requires technical skill, cutting-edge technology, calibration, processing time, and risk of malfunction or error due to the implicated additional computations. Based on the reasons above, qualitative analysis remains the preferable approach to sports practitioner to solve any problems related to movement (Knudson, 2007). This includes PE teachers when they are trying to find movement errors in their students through assessment.

Based on the aspect evaluation and 10 verified indicators, a content validity index (I-CVI) of more than 79 percent was produced for each item. Therefore, all items were classified as appropriate (Abdollahpour et al., 2010). The indicators represent the three principles of good assessment: setting a clear objective and keep the work aligned with the objective; having a good knowledge of movement that is being measured against; and make sure validity as well as reliability of the instrument (Capel & Whitehead, 2010). This demonstrates that the established observation checklist model has been officially classified. The observation checklist approach, which is based on qualitative biomechanics analysis, necessitates a strong supporting system, including basic biomechanics knowledge of movement principles and a clear mental image of the skill being rated. Teachers who are supposed to use this checklist also need to understand how to make use of every feature on the checklist table, including reading observation hints and giving checklists on the given grade box based on observed performance.

Effectivity of biomechanics assessment form

The third aspect is concerning the effectiveness of the biomechanics assessment instrument to determine the movement quality of students. Because it meets the following indicator, the model is classified as effective: (1) Biomechanics content accuracy is at least 78% on the percentage questionnaire scale; (2) volleyball content accuracy is at least 85% on the percentage questionnaire scale; and (3) the model is well received by the teacher. The utilization of an observation checklist based on biomechanics assessment can be used and is not limited to volleyball's underhand pass. It encompasses various sports and physical activities. The checklist should be useful in both face-to-face and online teaching. Therefore, it is suitable for use during or after COVID-19 pandemic education restriction. This form allows motion assessments to be carried out anywhere and anytime. This form can be used to assess live movements or recorded movements that have been collected. The assessment guidelines and supporting information in the form allow this instrument to effectively guide the validator to identify motion and provide an objective and directed assessment.

5. Conclusion

The following is a summary of some of the research's findings. First, PE teachers already have a problem with their assessment practices. Teachers must have a clear aim, a clear target, sound design, effective communication, and student involvement to have a high-quality assessment. The assessment technique being widely used by teachers in assessing students is observation. Before the COVID-19 pandemic, when teaching was still done face-to-face, the problem that occurred on assessment was the discrepancy between reported PE goals and assessment practice. There are

also PE teachers who do not have a basic understanding of biomechanics. Therefore, they based their feedback solely on their subjective experience of the movement without a strong basis in fundamental movement science. ince the closure of schools and the shift of class activity to online during the COVID-19 pandemic, problems with assessment have grown worse. Teacher and student are still not adjusted to the new situation, making the assignment and assessment less significant.

Second, the assessment instrument's initial design is based on a qualitative biomechanics analysis that is provided in the form of an observation guide and a table. The biomechanics theory of nine principles of movement is being used as the theoretical background of the model, and the volleyball's underhand pass was selected as the object of study case. The supporting system of the assessment model, including basic knowledge of biomechanics, knowledge of the movement, and operational knowledge of the checklist table, is necessary prior to using this model to make the assessment. Third, the effectiveness of an observation checklist based on qualitative biomechanics analysis values is shown by the fulfillment of criteria for validity, practicality, and effectiveness.

6. Recommendations/Future directions

The purpose of this study is to design an assessment instrument based on biomechanical principles that physical education teachers can use to evaluate the movement of their students. While this research only focuses on underhand service in volleyball, further study is needed to develop the instrument across technique in various sports. Given the product of this research, which is still paper-based, future studies need to address the instrument in a digital form that would likely be used on smartphones. Moreover, it is recommended that the design of future assessment instruments adhere to the principles of motion and knowledge of the sport so that the coach or teacher will easily understand the product without eliminating biomechanical content.

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Appendices

The following are biomechanical instruments for assessment of the quality of students' skill in the underhand pass of volleyball. Instruments are arranged in the form of checklists used by sports teachers when making observations. The checklist is presented in Bahasa Indonesia.

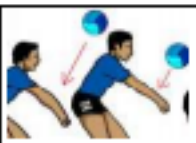
FORMULIR PENILAIAN GERAK

BiViSiS
Pratical is essential

Parameter	Indikator/Fase	Objek pengamatan	Skor: Berikan tanda (√) pada gerakan yang sesuai	Komentar
Tujuan Gerak	Bola diterima oleh kawan dengan mudah	Bola tidak melenceng dan mengenai target sasaran	☐ 40	
Tujuan mekanik	Fase persiapan			
1. Menjaga keseimbangan tubuh dengan menempatkan titik berat tubuh berada diantara kaki tumpuan 2. Mengunci torsi pada sendi bahu.		Kepala: 1. Pandangan terpusat ke arah datangnya bola	☐ 5	
		Lengan dan tangan: 1. Siku diluruskan 2. Lengan dirapatkan dan tempatkan di depan badan hingga kedua ibu jari sejajar	☐ 5	
		Badan: 1. Punggung diluruskan 2. Berat badan berada diantara kedua kaki	☐ 5	
		Kaki: 1. Kaki dibuka selebar bahu	☐ 5	
Tujuan mekanik	Fase gerakan inti			
1. Otot bahu depan berkontraksi menarik lengan ke atas, menyalurkan gaya untuk		Kepala: 1. Pandangan diarahkan ke target passing	☐ 5	

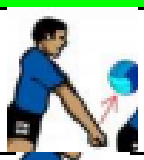
FORMULIR PENILAIAN GERAK

BiViSiS
Pratical is essential

menumbuk bola. Bola akan memantul ke arah sebaliknya jika momentum lengan lebih besar dari momentum bola ($m_1v_1 > m_2v_2$). 2. Proyeksi pukulan berada di rentang 0-90 derajat. Semakin jauh sasaran maka semakin kecil sudut pukulan. Jarak optimal terjauh dari bola dapat dicapai dengan proyeksi pukulan 45° 3. Momentum pukulan sejatinya diawali dari tubuh dan ditransfer ke lengan. Hanya mengandalkan lengan akan membuat pukulan tidak optimal karena gaya kinetik yang dihasilkan terlalu kecil.		Lengan dan tangan: 1. Kedua lengan diayun menyongsong arah datangnya bola dari bawah ke atas sampai setinggi bahu 2. Saat mengayun, siku tetap lurus 3. Bola dikenakan pada lengan diatas pergelangan tangan	☐ 5	
		Badan: 1. Punggung diluruskan 2. Berat badan condong ke depan	☐ 5	
		Kaki: 1. Kaki terkuat melangkah ke depan 2. Bola berada diantara kedua kaki ketika hendak dipukul	☐ 5	

FORMULIR PENILAIAN GERAK

BiViSiS
Pratical is essential

Tujuan mekanik	Fase gerak lanjutan			
1. Memastikan sudut proyeksi tetap terjaga hingga saat terakhir kontak dengan bola. 2. Memastikan pergeseran berat badan ke depan akan menghasilkan momentum pukulan $F = m\alpha = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t}$.		Kepala: 1. Pandangan ditujukan kearah bola	☐ 5	
		Lengan dan tangan: 1. Telapak tangan tetap menggenggam 2. Siku tetap lurus	☐ 5	
		Badan: 1. Berat badan berada diantara kedua kaki	☐ 5	
		Kaki: 1. Lutut diluruskan	☐ 5	

Skor akhir:

KURANG	CUKUP	BAIK
☐	☐	☐
0-45	50-75	80-100