



Sport Biomechanics in Handball: Analysis and Evaluation of One-Hand Pass Technique

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ABSTRACT

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This study describes the biomechanical characteristics of the basic one-hand pass movement in handball performed by senior high school students. A descriptive quantitative design was used, with video analysis as the main method of data collection. Ten students who had previously received handball instruction participated in the study. Each student performed three one-hand pass trials, resulting in 30 movement trials for analysis. The recorded movements were analyzed using Kinovea to obtain measurements of elbow angle, shoulder angle, knee angle, foot width, and throwing time. The data were summarized using minimum, maximum, mean, and standard deviation values. The results showed variation in the movement characteristics among the students. The mean elbow angle was $68.18 \pm 48.47^\circ$, while the mean shoulder angle was $81.36 \pm 30.71^\circ$. The mean knee angle was $164.27 \pm 12.19^\circ$, and the average foot width was 85.42 ± 19.31 cm. The average throwing time was 1.38 ± 0.67 s. These findings show that students performed the one-hand pass with different joint positions, foot support widths, and movement durations. The results provide a description of the biomechanical characteristics of the one-hand pass among senior high school students and may serve as a reference for evaluating and improving the learning of basic handball skills.



INTRODUCTION

Handball is one of the team sports characterized by dynamic gameplay with complex physical demands and fundamental movement skills. During matches, players perform various activities such as running, jumping, changing direction, and throwing, which require good physical abilities and fundamental movement skills (Árnason et al., 2026). These demands make physical abilities and movement coordination important components in supporting handball players' performance (Serrien & Baeyens, 2018).

One of the important fundamental movements in handball is passing, particularly the *one-hand pass* or one-handed pass. This movement plays a role in maintaining ball possession, connecting play between players, and supporting the attacking process (Árnason et al., 2026). The execution of the *one-hand pass* involves the coordination of movements across various body segments; therefore, movement quality does not depend solely on arm movement. A biomechanical approach can be used to objectively analyze the characteristics of fundamental handball movements by observing body position, joint movements, and intersegmental coordination (Bhakti et al., 2024).

The execution of the *one-hand pass* is related to the body's ability to generate and control movement in a coordinated manner. In throwing movements in handball, the shoulder is one of the important components of the *kinetic chain*, which plays a role in transferring energy from the body segments to the arm and the ball. Biomechanical aspects that can be observed include movement kinematics and kinetics, joint angles, movement velocity, and intersegmental coordination (Al Ardha et al., 2023, 2024; Skejød et al., 2019).

Intersegmental coordination is also an important component in producing effective movement. Research on *proximal-to-distal sequencing* in handball indicates that throwing movements involve a sequence of coordination from more proximal body segments toward distal segments (Moreno et al., 2020). This coordination pattern demonstrates the importance of the involvement of the pelvis, trunk, shoulder, and elbow in producing effective and controlled movement (Serrien & Baeyens, 2018).

In addition to movement coordination, the quality of the *one-hand pass* can be examined through biomechanical characteristics of the movement. The execution of the *one-hand pass* involves coordinated movement of the upper and lower limbs, including the positioning of the shoulder, elbow, and knee, as well as foot placement and the time required to perform the throwing movement. These characteristics can provide information about how students perform the fundamental movement during handball learning. Research on throwing performance in handball players indicates that movement characteristics, including movement speed and technical execution, can be examined through biomechanical analysis (Hadjisavvas et al., 2024).

During the execution of the *one-hand pass*, differences in body positioning, weight transfer, intersegmental coordination, arm movement, and ball release may influence the characteristics of the movement. Therefore, biomechanical analysis is needed to obtain a more objective description of movement characteristics and to identify aspects of the fundamental movement that need to be improved (Jatra et al., 2024). A biomechanical



approach can provide information that supports the evaluation and improvement of fundamental movements in handball learning and training (Bhakti et al., 2024).

Although research on the biomechanics of fundamental movements in handball has continued to develop, previous studies have largely examined the biomechanical characteristics of throwing movements and player performance (Vila & Ferragut, 2019). However, studies that specifically describe the biomechanical characteristics of the fundamental *one-hand pass* movement in senior high school students are still limited (Marin et al., 2024). Therefore, further analysis is needed to describe the execution of the *one-hand pass* at the learning level, particularly in relation to body position, movement coordination, weight transfer, joint movement, foot placement, and throwing time.

Based on this consideration, the present study aims to analyze the biomechanical characteristics of the fundamental *one-hand pass* movement in handball during the preparation, execution, and *follow-through* phases by examining shoulder angle, elbow angle, knee angle, foot width, and throwing time (Abdurrochim et al., 2016). The findings of this study are expected to provide useful information for students, Physical Education teachers, and coaches in evaluating and improving the fundamental *one-hand pass* movement through a more objective understanding of its biomechanical characteristics (Yudho et al., 2022).

METHODS

Research Design

This study employed a descriptive quantitative method with an approach to sports biomechanical analysis. The study was conducted to describe the characteristics of the basic *one-hand pass* movement among senior high school students in terms of biomechanical aspects and passing accuracy. The analysis process was based on video recordings that were divided into three movement phases, namely the preparation, execution, and *follow-through* phases. The biomechanical parameters analyzed included shoulder angle, elbow angle, knee angle, foot width, and throwing movement duration, while passing effectiveness was determined based on the accuracy of the ball in reaching the target. All data obtained were subsequently analyzed descriptively to provide an overview of the characteristics of the *one-hand pass* movement among the study participants.

Participants

The participants in this study consisted of 10 senior high school students who had received basic handball instruction and were able to perform the basic *one-hand pass* movement. The participants were selected using purposive sampling based on several criteria, namely understanding the basic *one-hand pass* movement, being willing to participate in the entire research process, and having no injuries that could interfere with the execution of the movement. Each participant performed the basic *one-hand pass* movement three times, resulting in a total of 30 trials, which were subsequently recorded and analyzed based on the predetermined biomechanical parameters.



Instruments

The instruments used in this study included a camera or smartphone, tripod, handball, measuring tape, and observation sheet. The camera or smartphone was mounted on a tripod from a side position to produce stable recordings and capture the participant's entire movement while performing the *one-hand pass*. Participants used a standard handball to perform the throw, while a measuring tape established both the target distance and foot stance width. We processed the resulting video footage through motion analysis software to extract key parameters, including shoulder, elbow, and knee angles, along with movement timing from backswing to release. We also monitored body posture and segment coordination across each movement phase, logging all kinematic outputs directly onto structured observation sheets.

Measurement Variables

We evaluated five primary variables: shoulder, elbow, and knee joint angles, base stance width, and total throw duration. Using motion tracking software, joint kinematics were calculated from anatomical landmarks visible in the video frames and reported in degrees (°). We recorded foot stance width in centimeters (cm) during the setup phase to assess base stability. Throwing time, measured in seconds (s), spanned from the initial backswing motion to the exact frame of ball release. These kinematic parameters provided a detailed biomechanical profile of each participant's passing technique.

Research Procedure

Before starting the test sessions, we explained the research goals and testing steps to the participants and guided them through a warm-up. Standardizing the testing field involved marking precise release lines and target boundaries, holding the throwing distance constant across all trials to serve as an experimental control. Video recording utilized two tripod-mounted cameras elevated at 150 cm: one positioned 5 meters to the side for lateral capture and another placed 6 meters directly in front. Unchanged camera coordinates across all sessions guaranteed clear, uninterrupted tracking of anatomical markers for kinematic processing. This optical arrangement aligns with recognized frameworks for assessing joint angles, movement traits, and stance stability in fundamental handball actions (Bhakti et al., 2024; Jatra et al., 2024).

Every participant completed three attempts of the basic one-hand pass aimed at the set target, generating 30 recorded trials in total. Recording was conducted from the time the participant was in the starting position until the *follow-through* movement was completed. The video recordings were subsequently analyzed using the motion analysis application Kinovea (Moreno et al., 2020). During the preparation phase, shoulder angle, elbow angle, knee angle, foot width, and throwing time were measured. The angle measurements were based on anatomical landmarks visible in the video recordings, while foot width was measured based on the distance between the two feet as an indicator of the basic support position. Joint angle and support position parameters were used as part of the analysis of the



biomechanical characteristics of the movement (Abdurrochim et al., 2016; Bhakti et al., 2024).

During the execution phase, movement time was measured as the duration from the moment the ball began to be pulled backward until the ball left the hand. The starting point was determined from the frame in which the backward movement of the ball first became visible, while the endpoint was determined from the frame in which the ball had been released from the hand (Skills et al., 2009). In addition, body movement and ball release position were observed to describe intersegmental coordination during the execution of the *one-hand pass*. The observation of coordination was based on the concept of *proximal-to-distal sequencing*, namely the sequential involvement of body segments from the more proximal parts toward the more distal parts during the handball throwing movement (Serrien & Baeyens, 2018).

All measurement results for each participant were recorded on an observation sheet, including shoulder angle, elbow angle, knee angle, foot width, and *one-hand pass* movement time. Thus, 30 trial data were obtained from 10 participants, with each student performing three *one-hand pass* trials. All data were then collected and analyzed descriptively to describe the biomechanical characteristics of the *one-hand pass* movement among senior high school students (Kartiko et al., 2019).

Statistical Analysis

Data analysis in this study was conducted descriptively using IBM SPSS Statistics. The data analyzed consisted of five biomechanical parameters, namely elbow angle, shoulder angle, knee angle, foot width, and throwing time during the *one-hand pass* movement. Data collection was conducted over three trials for each participant, resulting in 30 measurement data points from 10 students. We processed the dataset using standard descriptive parameters, calculating minimum, maximum, mean, and standard deviation values across all trials. To observe individual kinematic patterns, we also averaged each student's three attempts. Because our primary goal was to map the biomechanical profile of the one-hand pass rather than evaluate correlations or causal effects between variables, the analytical approach remained strictly descriptive.

Sample Characteristics

Ten senior high school students with prior foundational handball training participated in this study. We selected participants using purposive sampling based on three specific criteria: competency in executing the basic one-hand pass, full commitment to the complete testing protocol, and freedom from musculoskeletal injuries that might alter movement execution. Each student completed three passes, yielding 30 total recorded trials for biomechanical analysis.

**Table 1.** Characteristics of the Research Sample Based on Age and Sex

Participant	Age	Sex
P01	17	Male
P02	16	Male
P03	16	Male
P04	16	Male
P05	15	Male
P06	17	Female
P07	16	Female
P08	16	Female
P09	16	Female
P10	16	Female

Table 2. Characteristics of the Research Sample

Characteristic	Description
Number of participants	10 senior high school students
Number of trials	30 trials
Percobaan of partisipant	3 trials
Sampling technique	Purposive sampling
Skill analyzed	One hand pass
Main criteria	Possessed foundational handball training and demonstrated competency in executing a one-hand pass.
Participant condition	Were free from physical injuries that could impair execution.

RESULTS

The biomechanical analysis results were obtained from 30 *one-hand pass* trials performed by 10 senior high school students. We then analyzed the collected dataset using descriptive metrics across all five core parameters: elbow angle, shoulder angle, knee angle, stance width, and execution duration. Calculating minimum, maximum, mean, and standard deviation values for each variable captured the baseline variance and range across individual attempts.

Table 3. Descriptive Statistics of One-Hand Pass Biomechanical Parameters

Parameter	N	Minimum	Maximum	Mean	SD
Elbow angle (°)	30	-145.2	134.7	-68.18	48.47
Shoulder angle (°)	30	5	136.3	81.36	30.71
Knee angle (°)	30	140.8	179.9	164.27	12.19
Foot width (cm)	30	38.67	115.97	85.42	19.31
Throwing time (s)	30	0.50	3.41	1.38	0.67



As outlined in Table 3, elbow angle measurements averaged $-68.18 \pm 48.47^\circ$, spanning from a minimum of -145.20° to a maximum of 134.70° . Shoulder elevation yielded a mean of $81.36 \pm 30.71^\circ$, with individual values ranging between 5.00° and 136.30° . Knee joint mechanics showed a mean extension of $164.27 \pm 12.19^\circ$, bounded by a low of 140.80° and a high of 179.90° .

Regarding base stability, participants recorded an average foot stance width of 85.42 ± 19.31 cm, with absolute values ranging from 38.67 to 115.97 cm. Finally, execution timing averaged 1.38 ± 0.67 seconds, where throw duration varied from a rapid 0.50 seconds to a peak of 3.41 seconds.

Results Based on the Mean Values of Each Participant

Table 4. Mean Values of Three Trials for Each Participant

Participant	Elbow (°)	Shoulder (°)	Knee (°)	Foot Width (cm)	Time (s)
P01	-102.9	120.3	175.33	94.5	1.11
P02	-33.97	32.83	169.6	90.36	1
P03	-97.6	88.83	175.33	88.55	0.8
P04	-48.03	94.33	153.6	83.23	0.9
P05	-97.8	74.47	178.87	89.65	0.98
P06	-49.67	122.83	152.23	45.09	2.71
P07	-63.77	96.63	151.67	90.98	2.31
P08	-55.33	42.97	150.37	99.18	1.19
P09	-63.87	79.5	169.1	105.93	1.26
P10	-68.83	60.87	166.63	66.73	1.55

Averaging the three trials per participant highlighted notable individual variability across all biomechanical variables. Subject elbow angle means spanned from -102.90° to -33.97° , while mean shoulder elevation ranged between 32.83° and 122.83° . Knee extension averages fluctuated from 150.37° to 178.87° . For base stability, individual mean foot stance widths varied from 45.09 cm to 105.93 cm. Throwing efficiency also showed clear differences, with average trial times ranging between 0.80 and 2.71 seconds.

DISCUSSION

Biomechanical analysis confirmed clear performance variations in the high school students' one-hand pass execution across all five key metrics: joint angles (elbow, shoulder, knee), base foot stance width, and execution time. These physical variances confirm that performing a successful pass requires full-body kinetic integration—linking leg positioning, base balance, and execution timing with arm action. Such whole-body coordination reinforces the findings of (Van Den Tillaar & Ettema, 2007), who emphasized that core handball mechanics involve a dynamic synergy of joint angles, body balance, kinematic patterns, speed, and adaptive movement (Ilham Nur Ardian, 2018).



Shoulder joint kinematic analysis yielded an average angle of 81.36° , underscoring its functional role in guiding arm trajectory during the throw. As established by (Marin et al., 2024; Skejød et al., 2019), shoulder mechanics serve as a cornerstone of handball throwing performance, with successful execution demanding significant rotational shifts at the shoulder joint. Unsurprisingly, discrepancies in kinematic findings between studies usually stem from differing measurement frameworks and data processing methods (Segita & Raharjo, 2026).

Across all attempts, the knee joint angle yielded a mean value of 164.27° , with a standard deviation recorded at 12.19° . This value indicates that the measurement results for knee angle across trials had relatively lower dispersion compared with several other parameters. The position of the lower limbs and feet also contributes to the movement sequence when students perform the *one-hand pass*. Nevertheless, this study was only intended to describe movement characteristics and therefore cannot yet explain whether changes in knee angle are directly related to the quality or success of the basic *one-hand pass* movement (Kartiko et al., 2019).

Furthermore, foot width showed a mean value of 85.42 cm with a standard deviation of 19.31 cm. This result indicates differences in the distance between the feet used by each participant when preparing for the movement. In this study, foot width was used to describe the basic support position during the *one-hand pass*. In handball biomechanics research, support position and postural stability are among the aspects that can be observed to examine the characteristics of a movement. This is consistent with (Bhakti et al., 2024; Lesmana et al., 2024), who included *postural stability* and *movement pattern* as parameters in the biomechanical analysis of basic handball movements.

For the throwing time parameter, the mean value obtained was 1.38 ± 0.67 seconds. The differences in throwing time indicate that each participant had a different movement execution duration, from the beginning of the movement until the ball was released. However, movement execution time cannot be used as a basis for determining whether a basic movement is better or worse. This is because the present study was descriptive in nature and did not analyze the relationship between throwing time and passing outcome. Therefore, throwing time in this study was used as one of the indicators to describe the kinematic characteristics of the movement (Árnason et al., 2026).

Comparing individual participant averages further highlights these kinematic contrasts. Subject P03, for instance, completed throws in an average of 0.80 seconds, whereas P06 recorded a much longer average duration of 2.71 seconds. These differences indicate that the execution of the *one-hand pass* may occur over different durations among students. However, these differences cannot be used as a basis for stating that participants with shorter throwing times had more effective basic movements. This is because the study did not measure ball velocity or examine the relationship between movement duration and passing effectiveness.



Overall, incorporating video analysis into this study enabled a more precise, objective evaluation of how high school students execute the basic one-hand pass. Quantifying joint angles, base support width, and movement timing offered clear insight into individual technique variations during execution. This reinforces the value of biomechanical evaluation in handball research, where movement patterns are best understood through measurable physical parameters (Nur et al., 2021; Vila & Ferragut, 2019).

Ultimately, this research provides an initial quantitative baseline for one-hand pass biomechanics in high school students across five selected metrics. Subsequent studies can expand this framework by incorporating parameters like ball speed, release trajectory mechanics, target accuracy, and joint coordination timing. Evaluating these extra dimensions will yield a more thorough understanding of passing technique and overall movement execution (Rohman & Hananto Puriana, n.d.; Wagner et al., 2010, 2011).

CONCLUSION

Physical performance during the basic one-hand pass varied noticeably among high school participants across the five primary metrics evaluated: elbow angle, shoulder angle, knee angle, stance width, and throwing duration. Motion analysis across 30 total executions by 10 participants generated mean values of $-68.18 \pm 48.47^\circ$ for elbow angle, $81.36 \pm 30.71^\circ$ for shoulder angle, $164.27 \pm 12.19^\circ$ for knee angle, 85.42 ± 19.31 cm for foot stance width, and 1.38 ± 0.67 seconds for throwing time. This broad spread underscores that successful passing relies on whole-body mechanical integration, uniting upper-limb propulsion with lower-body balance, base stability, and timing. Consequently, these findings establish a practical baseline for high school passing biomechanics, laying the groundwork for subsequent studies to examine ball speed, release mechanics, throwing accuracy, and multi-joint coordination.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.



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