

Applicability of observational standards for softball throwing to handball overhand throwing movements

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Abstract

Overhand throwing is a fundamental movement that is commonly used to assess basic physical fitness in Japan. Observational evaluation standards have been developed to evaluate, improve, and enhance overhand throwing technique and performance. However, these standards are primarily designed for hand-sized objects such as softballs or tennis balls, and there are no established standards specifically for throwing larger objects, such as handballs. This study investigated whether the key factors of observational movement evaluations are consistent or different when comparing overhand throws of a handball, which is larger than a hand, to those of a softball, which is smaller. The 40 male college students who participated performed handball throwing with maximum effort twice. The farthest throwing distance of the two trials was used for analysis. Participants' motions were recorded by two video cameras and observationally evaluated by four different researchers using established softball standards. Each movement was evaluated on a three-point scale (3, excellent; 2, fair; 1, poor). To determine the impact of each movement on the throw, stepwise multiple regression analysis was conducted, with the throw as the dependent variable and the evaluation results for each movement as independent variables. The kinematic chain of the throwing arm, leading action of the free arm, and trunk tilt were crucial to the outcome and remained fundamental to effective handball throwing, just as they are in softball throwing. In contrast, the relation between the shoulder and elbow, backswing action, trunk twist, trunk direction, step length, and shifts in body weight were less important for handball throwing, likely due to the ball's diameter and mass. These findings highlight the importance of developing specific observation evaluation standards tailored to overhand throw movements using a large ball.

Key Words: basic physical fitness, ability, skill, criteria

Introduction

Overhand throwing is a fundamental movement in numerous sports such as baseball, javelin throw, American football, water polo, cricket, and team handball (Bartlett, 2000; Fowler, 2007; van den Tillaar, 2004). This movement, particularly when executed with maximal effort, is widely used as a measure of basic physical fitness in both the United States and Japan (Mathews, 1978; McCloy & Young, 1954). In Japan, overhand throw distance has been measured since 1964 to assess physical fitness across different age groups, with elementary students typically using softballs and junior high and high school students using handballs (Kidokoro et al., 2022; *mext.go.jp*, 2023). The assessment provides valuable insights into motor skill development and basic physical fitness, yet the applicability of established evaluation standards to different ball sizes and weights remains unclear.

Despite the widespread use of overhand throwing tests, the size and weight of the ball may significantly influence throwing mechanics. The difference in weight between a softball (136–146 g) and a handball (325–400 g) can influence the overhead throwing movements due to the force–velocity relationship (Hill, 1938). Additionally, the size difference between the two balls (softball diameter: 8.5 cm, handball diameter: 18.0 cm) relative to the hand may also affect the movement (Bartlett, 2000; Burton et al., 1992). Using an overweight or lower-weight ball may increase the velocity of overhand throws through overloading force or velocity training, respectively (van den Tillaar, 2004). Given this effect of ball weight and size on throwing movements and training effectiveness, it is crucial to examine whether the fundamental throwing movements remain consistent when the size and weight of the thrown object change.

Observational evaluation is a qualitative method for biomechanical analysis that aids in the evaluation of sports techniques and training, as well as injury prevention (Hay & Reid, 1988; McGinnis, 2013). Specific characteristics of overhand throwing movements have been identified, and observational evaluation standards

(OESs) have been developed to provide appropriate instruction and to improve and enhance the performance of this skill (Halverson et al., 1982; Haywood et al., 1991; Knudson & Morrison, 1996; Takizawa & Kondoh, 2017). However, current OESs are primarily designed for throws using balls that are equal to or smaller than the hand, such as softballs and tennis balls (Knudson & Morrison, 1996; Takizawa & Kondoh, 2017). It remains unclear whether these standards apply to the evaluation of overhand throws with larger balls relative to the hand, such as handballs, which may require different movement adaptations.

This uncertainty is particularly concerning in the context of declining throwing abilities among Japanese youth, a trend that is evident across various physical fitness levels (*mext.go.jp*, 2023). Because overhand throws with larger, heavier balls, such as handballs and basketballs, are common, it is essential to determine whether the critical movements observed for softball overhand throws apply to these larger balls. If the mechanics of throwing differ significantly between softballs and handballs, relying on a single set of evaluation criteria could lead to inaccurate assessments and hinder efforts to improve throwing performance. Accurate evaluation is a critical first step toward developing effective training programs that enhance overhand throwing performance, and by extension, overall physical fitness among youth.

To address these concerns, we studied whether the key factors in observational movements remain consistent or are different between ball types. Ultimately, this work could help to improve motor skill development and physical fitness among Japanese youth, addressing a critical area of concern in contemporary sports and physical education.

Materials & Methods

Participants

In all, 40 healthy male college students participated; 37 were right-handed and 3 were left-handed. All participants provided written informed consent prior to the experiment.

Data collection

After a warm-up session, each participant performed two consecutive overhand throws with a handball. The trials were performed at maximum effort, with throwers confined to a circle with a diameter of 2 meters. Participants were allowed to perform preparatory movements, such as stepping within the circle, at their discretion. The distance from the throwing position to where the ball landed was measured using a tape measure and recorded in centimeters.

The throwing motion was filmed by two high-speed cameras (GC-LJ25BM, JVCKENWOOD Co., Japan) from two directions, one to the right of the throwing direction and the other to the rear, at 120 fps, with an exposure time of 1/2500 s and an image field of 640 × 360 pixel. The time axes of the two cameras were synchronized by firing an LED strobe (LF301Bi, Godox Co., China) during the trial. The experiment was approved by the ethics committee of Kyoto University of Advanced Science (21-513).

Observational evaluations

We used established OESs to assess overhand throws of softballs (Aburano et al., 1995; Haywood et al., 1991; Robertson & Halverson, 1984; Takizawa & Kondoh, 2017; Williams et al., 1998). Then, using the four-member Delphi method, key movements were identified based on their importance and reliable evaluability (Linstone & Turoff, 1975). The expert members had experience in research and coaching in the field of throwing, with specializations in pedagogy, biomechanics, and growth and development.

The nine movements selected via the Delphi process were the kinematic chain of the throwing arm (Robertson & Halverson, 1984; Takizawa & Kondoh, 2017; Williams et al., 1998), the relation between the shoulder and elbow (Takizawa & Kondoh, 2017), backswing action (Aburano et al., 1995; Beseler et al., 2021; Haywood et al., 1991; Takizawa & Kondoh, 2017; Williams et al., 1998), trunk twist (Robertson & Halverson, 1984; Takizawa & Kondoh, 2017; Williams et al., 1998), trunk tilt (Aburano et al., 1995; Robertson & Halverson, 1984), trunk direction (Takizawa & Kondoh, 2017), step length (Aburano et al., 1995; Robertson & Halverson, 1984; Williams et al., 1998), the leading action of the free arm (Aburano et al., 1995), and shifts in body weight (Takizawa & Kondoh, 2017).

Observational evaluations were conducted by the same four experts using video playback software (QuickTime for Windows 7.7.9, Windows Co., US). Each movement was evaluated on a three-point scale (3, excellent; 2, fair; 1, poor), with details shown in Tables 1–3.

Generally, evaluation standards for observational movements are developed by statistically assessing validity, reliability, and objectivity across the observational results of each expert (Aburano et al., 1995; Takizawa & Kondoh, 2017). However, the established standards have already been validated (Aburano et al., 1995; Takizawa & Kondoh, 2017).

Therefore, the four experts conducted the evaluation simultaneously and unified the evaluation results into a single outcome, disregarding reliability and objectivity.

Table 1 Observational standards for throwing arm movements.

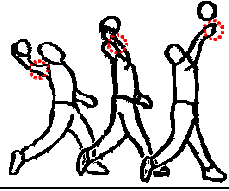
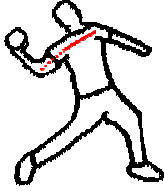
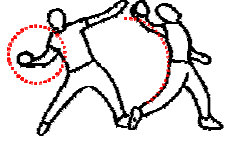
Throwing arm movements	Level	Details	Images of observational point
Kinematic chain	1	Hand, forearm, and humerus move simultaneously	
	2	Humerus leads, forearm and hand lag	
	3	Humerus, forearm, and hand move in that order	
Relation between the shoulder and elbow	1	Shoulder line and humerus do not straighten	
	2	Shoulder line and humerus straighten	
	3	Shoulder line and humerus straighten and incline posteriorly	
Backswing action	1	No backswing action	
	2	Linear action without whip-like motion	
	3	Circular action with whip-like motion	

Table 2 Observational standards for trunk movements.

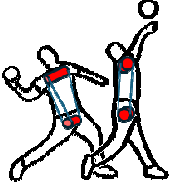
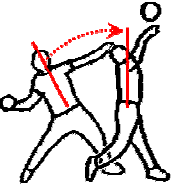
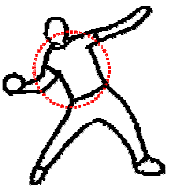
Throwing arm movements	Level	Details	Images of observational point
Twist	1	No twist	
	2	Twist without twist back	
	3	Twist and twist back until release	
Tilt	1	No tilt backward	
	2	Tilt backward	
	3	Tilt backward then movement forward	
Direction	1	Facing the direction of the throw	
	2	Facing diagonally forward on the side of the throwing arm relative to the direction of the throw	
	3	Facing directly to the side of the throwing arm relative to the direction of the throw.	

Table 3 Observational standards for step length, leading action of the free arm, and shifts in body weight.

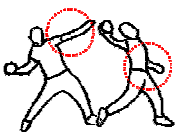
Other arm movements	Level	Details	Images of observational point
Step length	1	No step	
	2	Narrower than shoulder breadth	
	3	Equal to or wider than shoulder breadth	
Leading action of the free arm	1	No leading action	
	2	Point the free arm in the direction of throw	
	3	Point the free arm in the direction of throw and then pull it toward the trunk	
Shifts in body weight	1	Remains on the back leg	
	2	Shifts to above the foreleg	
	3	Shifts forward until it overtakes the foreleg	

Table 4 Mean and standard deviations in handball throwing distances and results of observational evaluation of nine movements.

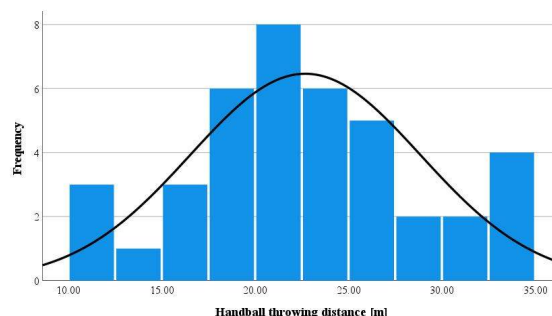
Handball throwing distance [m]	22.77 ± 0.53	
Observational score		
Kinematic chain of the throwing arm	1.78 ± 0.77	
Shoulder–elbow relation	1.83 ± 0.87	
Backswing action	2.05 ± 0.75	
Trunk twist	1.80 ± 0.91	
Trunk tilt	1.85 ± 0.89	
Trunk direction	2.88 ± 0.33	
Step length	2.03 ± 0.53	
Leading action of the free arm	2.08 ± 0.94	
Shifts in body weight	2.20 ± 0.48	
Total score	18.50 ± 4.23	

Statistical analysis

The total scores for the nine observed movements were calculated for each participant. The Shapiro-Wilk test was used to assess the normality of the throwing distance and the total score. The relationship between throwing distance and total score was examined using Spearman's rank correlation coefficient with 95% confidence intervals (95% CIs). Correlation coefficient thresholds were set as 0.1 (small), 0.3 (moderate), 0.5 (large), 0.7 (very large), and 0.9 (extremely large) (Hopkins et al., 2009). Multiple regression analysis, using the stepwise method, was performed with the throwing distance as the dependent variable and the evaluation results of each movement as independent variables to determine the impact of each movement. Statistical analysis was performed using SPSS version 27.0 (IBM, Tokyo, Japan), with statistical significance set at 5%.

Results

Table 4 summarizes the outcomes. The total score of the nine movements was significantly positively correlated with throwing distance (Fig. 2). Multiple regression analyses showed that the kinematic chain of the throwing arm, leading action of the free arm, and trunk tilt significantly impacted the throwing distance, while the other six movements did not.

**Fig. 1** Histogram of handball throwing distances of participants.

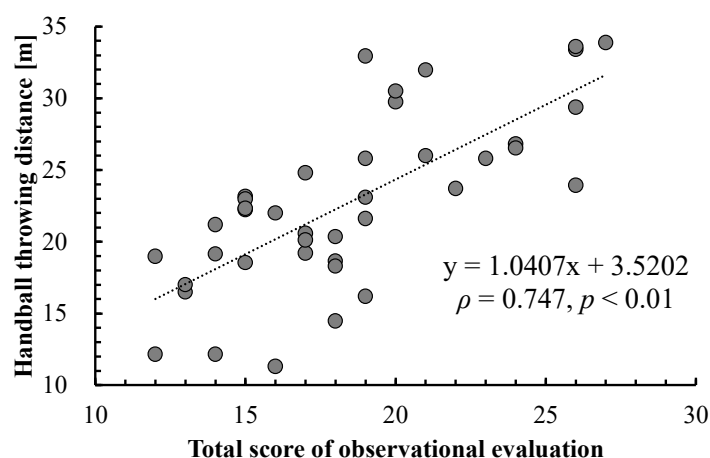


Fig. 2 Relationship between handball throwing distances and total scores.

Discussion

We investigated whether the key factors of observational movement evaluations were consistent or different when comparing overhand throws of a handball to those of a softball. We found a very strong correlation between total scores and handball throwing distance, indicating that higher scores corresponded to better throwing performance. However, stepwise analysis using handball throwing distance as the dependent variable indicated that the relation between the shoulder and elbow, backswing action, trunk twist, trunk direction, step length, and shifts in body weight were less relevant.

On the other hand, these six movements are crucial in softball throwing. In the overhand throw, trunk twist and twist-back motions help to transfer torque from the hip to the torso and the torso to the shoulder, following a kinematic chain (Matsuo & Fleisig, 2006). The overhand throw begins with a shift in the center of gravity from the back leg to the front leg (Trasolini et al., 2022), and this aids the transfer of energy to the throwing arm (Takizawa & Kondoh, 2017). Similarly, step length and stepping the leg toward the throwing direction initiate the transfer of weight and kinematic energy from the lower extremities to the trunk (Williams et al., 1998). Therefore, a larger step length may affect shifts in body weight and both trunk twist and twist back movements.

A longer backswing also increases the time and distance through which force can be applied to the ball, potentially resulting in a higher release velocity (Beseler et al., 2021; Haywood et al., 1991; Robertson & Konczak, 2001). In elementary school students' overhand throwing of a tennis ball, the backswing score correlated with ball velocity (Beseler et al., 2021). Additionally, in terms of the relation between the shoulder and elbow, higher scores indicated better overall throwing skills with a softball in such students (Takizawa & Kondoh, 2017). Because the backswing action precedes and potentially affects the relation between the shoulder and elbow, it can be assumed that these elements are interconnected.

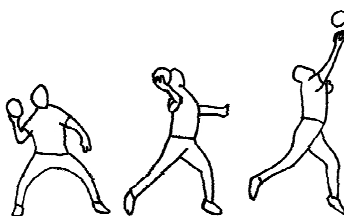


Fig. 3 Example of a participant who held the ball from below and threw it without stepping.

As shown in Fig. 3, several participants in our study held the handball from below and threw without stepping, a deviation likely influenced by the diameter and mass of the handball. Compared to a softball, a handball is approximately twice as large in diameter and mass, which may affect grip and throwing movement (Bartlett, 2000; Burton et al., 1992). Although the hand sizes of the participants were not measured, they seemed to struggle to hold the handball, and the throwing motion differed from that seen with a softball, often without a backswing or stepping action. This implies that movements such as shifts in body weight, trunk twist, and the relation between the shoulder and elbow may function differently in handball versus softball throwing.

Stepwise analyses revealed that the kinematic chain of the throwing arm, the leading action of the free arm, and trunk tilt were critical movements in handball throwing, just as they are in softball throwing. In overhand movements such as throwing, a proximal-to-distal segmental sequence occurs, with the upper limb accelerating sequentially from the distal to the proximal part of the body, and maximum speed occurring in the same order (Marshall & Elliott, 2000). This type of sequence, known as the kinematic chain, contributes to

efficient acceleration of the hand and of the object being thrown (Blazevich, 2017). The lag of the throwing arm segments evaluated in this study reflects this proximal-to-distal segmental sequence and kinematic chain, underscoring its importance in handball throwing. In baseball pitching, for example, the free arm initially extends in the throwing direction and is then drawn back toward the trunk, helping to control the inertia moment associated with this motion and contributing to an increase in ball velocity (Ishida & Hirano, 2004). Similarly, the degree of forward trunk tilt at release contributes to both the energy transferred from the trunk and to the dynamic interactions among the upper extremity movements (Stodden et al., 2006). The roles of the leading action of the free arm and trunk tilt are crucial in both softball throwing and baseball pitching, and this study confirmed their significance in handball throwing as well (Aburano et al., 1995; Robertson & Halverson, 1984).

There were some limitations to this study. The throwing distances of the participants were 11.30–33.87 m. However, the evaluation range for handball throwing distances in the Japanese physical fitness test is broader, with a minimum of less than 12 m to a maximum of more than 37 m (*mext.go.jp*, 2023). Consequently, our findings may not be fully applicable to observational evaluations of the movement across the entire range of distances. Additionally, because ball throwing is often examined from the perspective of growth and development and lifetime sports, including in children and the elderly, future research should investigate a wider range of ages and performance levels (Aburano et al., 1995; Halverson et al., 1982; Robertson & Halverson, 1984; Robertson et al., 1979; Robertson & Konczak, 2001; Takizawa & Kondoh, 2017; Williams et al., 1998). Furthermore, to develop new OESs for handball throwing, the movements of team handball may serve as valuable references, given that the sport involves handball throwing. However, it should be noted that the proximal-to-distal segmental sequence observed in overhand throws does not always occur in the throwing motion in team handball (Fradet et al., 2004; van den Tillaar & Ettema, 2009). Thus, there may be additional important movements specific to handball throws that were not examined in previous studies or in our study.

Conclusions

Observational evaluation of nine movements in handball throwing, using OESs originally developed for softball throwing, was conducted with a sample of 40 male college students. The results confirm that the kinematic chain of the throwing arm, the leading action of the free arm, and trunk tilt are critical for achieving greater handball throwing distances. In contrast, six movements, including the backswing action, step length, and trunk twist, were less significant in handball throwing, likely due to the effects of the diameter and mass of the ball. Our findings indicate that established OESs designed for smaller and lighter balls like softballs and tennis balls may not be fully applicable to sports involving larger and heavier balls, such as a handball. This discrepancy can lead to inaccurate assessments of throwing performance and hinder the effectiveness of training programs aimed at enhancing overhand throwing skills in these contexts. Therefore, there is a clear need to develop and implement specific OESs tailored to larger balls to ensure accurate and meaningful assessments.

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Author contribution

TAK conceived the study, participated in its design and coordination, performed the experiment and the statistical analyses, and drafted the original version of the manuscript. KEM participated in its design and coordination, performed the experiment, and helped in participants' recruitment. KOM and JUM conceived the study and participated in its design and coordination. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

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