



Relationship Between Arm Muscle Strength, Hand Flexibility, and Football Throw-In Performance in Vocational School Students

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ABSTRACT

The football throw-in is often treated as a routine restart, yet recent tactical and biomechanical research indicates that it can become an attacking weapon when distance, release quality, and legality are optimized. Evidence explaining the physical foundations of this skill at the school level, especially in Southeast Asia, remains limited. This study examined the correlation between arm muscle strength, hand flexibility, and throw-in performance among male students at SMK Negeri 1 Tenggara Seberang, Indonesia. A quantitative correlational design was used with 30 students randomly selected from a population of 130 participants in the school's physical education program. Arm muscle strength was assessed through a standardized push-up test, hand flexibility through goniometric wrist-hand range-of-motion measurement, and throw-in performance through legal throw-in distance based on the IFAB procedure. Data were analyzed using descriptive statistics, Pearson product-moment correlation, multiple correlation, and an F test at alpha .05. The results showed that there were very strong positive correlations between throw-in performance and arm muscle strength ($r = .932$) and between throw-in performance and hand flexibility ($r = .918$). The combined relationship was also very strong ($R = .938$; $F = 98.396$, $p < .05$), indicating that both variables together explained about 88% of the variance in throw-in distance. The study's novelty lies in examining strength and flexibility simultaneously among adolescent football players in an Indonesian vocational school context. The results confirm that upper-limb force production and distal joint mobility function as an integrated physical profile that underpins effective throw-in execution and supports age-appropriate upper-body strength and mobility training as part of football skill development.

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I. INTRODUCTION

Football remains one of the most widely played and analytically scrutinized team sports in the world, and seemingly small technical actions increasingly shape tactical margins. Recent performance analysis shows that the throw-in should no longer be treated merely as an administrative restart. In elite competition, throw-ins in advanced zones can support territorial progression, possession retention, and even chance creation when delivery direction, receiver timing, and body orientation are coordinated effectively (Casal et al., 2023; Kapelman et al., 2025). Under Law 15, however, the action is tightly constrained: the player must face the field, keep part of each foot on or outside the touchline, and deliver the ball with both hands from behind and over the head (The International Football Association Board, 2025). These restrictions make the throw-in biomechanically distinctive because players must maximize useful distance and control without compromising legality. In the Indonesian context, public interest in this skill has intensified with the tactical use of long throw-ins in national-team competition, most notably by Pratama Arhan, whose delivery has been examined as a direct mechanism for exerting attacking pressure (Kusuma et al., 2024). For school players, therefore, the throw-in is not only a basic technical requirement but a teachable opportunity to link physical conditioning with game effectiveness.

From a biomechanical perspective, the football throw-in is a coordinated overhead movement that depends on efficient energy transfer across the kinetic chain. Linthorne and Everett (2006) demonstrated that maximum throw-in distance is determined by the interaction of release angle, release speed, release height, and backspin, with the optimal angle falling below the idealized 45-degree projectile value because release speed decreases as the angle rises. More recent kinematic analysis confirmed that release velocity, release angle, and release height remain central determinants of throw-in distance, while segmental sequencing also contributes to effective execution (Radwan et al., 2024). Overhead-sport scholarship further shows that upper-extremity performance is produced by linked contributions from the trunk, shoulder complex, elbow, wrist, and hand rather than by a single segment acting in isolation (Ellenbecker & Aoki, 2020; Jones & Safran, 2024; Ramasamy et al., 2023). Within that framework, arm muscle strength provides the capacity to accelerate the ball, whereas hand and wrist flexibility may enlarge the effective path of motion and improve terminal control at release. These qualities are therefore not peripheral fitness traits but plausible physical determinants of a legal and tactically meaningful throw-in.

The principal problem at the school level is that football instruction often prioritizes sprinting, dribbling, passing, and kicking while giving comparatively little systematic attention

to upper-body conditioning and sport-specific mobility. In youth football, structured strength and power training have been shown to improve important outcomes, yet the most frequently studied variables remain sprint speed, jump performance, and change-of-direction ability rather than throw-in capability (Garcia-Carrillo et al., 2023; Oliver et al., 2024). As a result, many adolescent players perform throw-ins from short distances, with unstable body positioning or inconsistent release quality. In practical teaching situations, these technical limitations may reflect insufficient physical capacity as much as imperfect skill instruction. This issue is especially salient in school physical education, where training time is limited, classes are heterogeneous, and coaches need efficient interventions that improve both motor learning and observable performance. A broad solution advanced in the sport-science literature is to integrate technical rehearsal with targeted physical development so that movement skills are supported by appropriate force production, mobility, and coordination. For overhead football actions such as the throw-in, that solution implies strengthening the upper limbs while maintaining the joint mobility required to generate force efficiently and legally.

Specific solutions have already been reported in closely related literature. A systematic review and meta-analysis by Garcia-Carrillo et al. (2023) found that upper-body plyometric training improves maximal strength, medicine-ball outcomes, sport-specific throwing performance, and muscle volume in youth and young adult populations. Football-specific intervention studies point in the same direction. Push-up-based training improved standing throw-in distance in young players (Zainuddin et al., 2022), while recent experimental studies using medicine-ball drills, resistance bands, battle ropes, and medicine-ball throwing exercises reported significant gains in long throw-in ability among youth football athletes (Humam et al., 2025; Santoso & Hakim, 2026; Siddik et al., 2025; Vieri et al., 2025). At the mobility end of the continuum, stretching interventions remain an established way to improve range of motion where restriction exists in overhead athletes (Iida et al., 2025). Although football throw-ins differ from baseball pitches or volleyball serves, these findings collectively indicate that both upper-limb force production and mobility are trainable contributors to ballistic upper-extremity skill.

Despite this progress, the existing literature remains fragmented in ways that limit direct application to adolescent football education. First, many studies on throw-ins emphasize tactical outcomes or kinematic variables rather than the field-based physical characteristics that school coaches can assess and train directly (Casal et al., 2023; Kapelman et al., 2025; Radwan et al., 2024). Second, intervention studies generally evaluate one training modality at a time. Such work is useful for showing whether a program improves performance, but it does not clarify

how relevant physical characteristics coexist within players before training. Third, evidence on mobility-performance relationships is not uniform across overhead tasks. Telles et al. (2021), for example, found that passive shoulder rotation range of motion was not directly associated with volleyball serve speed after accounting for age and body size, whereas Ide et al. (2026) showed that strength and range-of-motion measures are more informative when interpreted together than in isolation. These inconsistencies point to a clear research gap: relatively little is known about the simultaneous relationship between arm muscle strength and hand flexibility and football throw-in performance among adolescent players in Indonesian or broader Southeast Asian school settings.

Accordingly, the present study investigated the relationships among arm muscle strength, hand flexibility, and throw-in performance among male students at SMK Negeri 1 Tenggara Seberang, Indonesia, in 2025. Using a quantitative correlational design, the study examined both bivariate associations and the combined relationship of the two predictors with throw-in distance. The study is novel because it integrates strength and flexibility into a single explanatory model in the context of vocational-school football, a field that remains underrepresented in the international literature. This contribution is relevant on both scientific and practical grounds. Scientifically, it extends the discussion of throw-ins beyond descriptive coaching advice toward an empirically testable biomechanical explanation. Practically, it offers evidence for teachers and coaches who must decide which physical qualities deserve priority when designing school-based football training. By linking current overhead-sport reasoning with a field-based school sample, the study seeks to clarify whether upper-limb force production and distal joint mobility function as complementary determinants of throw-in performance in adolescent players.

II. METHODS

This study employed a quantitative correlational design to examine the degree to which arm muscle strength and hand flexibility were associated with throw-in performance in football. Cross-sectional correlational designs are widely used in sports science when the aim is to describe naturally occurring relationships between measurable physical characteristics and a specific performance outcome under field conditions similar to normal practice (Bauer et al., 2022; Telles et al., 2021). The research was conducted at the football field of SMK Negeri 1 Tenggara Seberang, Kutai Kartanegara, East Kalimantan, Indonesia, from February to April 2025 during the regular physical education schedule so that testing conditions remained close to the students' authentic learning environment. The target population comprised 130 male

students enrolled in the school's physical education program. To reduce physiological heterogeneity that might obscure the observed associations, the analysis was restricted to male participants. Thirty students were then selected by simple random sampling, ensuring that each eligible student had an equal chance of inclusion in the study sample.

Three variables were analyzed: arm muscle strength (X1), hand flexibility (X2), and throw-in performance (Y). Their operationalization and measurement framework are summarized in Table 1. Arm muscle strength was assessed using a standardized push-up test, with the score recorded as the number of correct repetitions. Although the push-up test primarily serves as a field proxy for upper-body strength-endurance rather than a direct measure of maximal force, revised push-up protocols have demonstrated acceptable objectivity, reliability, and validity for assessing arm and shoulder-girdle performance in applied settings (Baumgartner et al., 2002). Field-based upper-body tests are also considered practical and sufficiently robust for youth populations when standardized instructions and scoring criteria are maintained (Fernandez-Santos et al., 2016). A recent Indonesian validation study likewise supports the feasibility of push-up-based arm-strength assessment in sport settings (Artanayasa et al., 2023). Hand flexibility was measured with a goniometer during controlled wrist and hand flexion and extension, and recorded in degrees. Goniometric range-of-motion measurement remains a standard tool in monitoring overhead athletes because it converts joint mobility into a directly interpretable quantitative metric (Iida et al., 2025; Telles et al., 2021). Throw-in performance was measured as the linear distance, in meters, achieved during a legal football throw-in performed according to IFAB procedure, namely a two-handed overhead throw with both feet positioned legally at release (The International Football Association Board, 2025).

Table 1. Measurement framework for variables X1, X2, and Y

Variable	Operational focus	Instrument and procedure	Unit
Arm muscle strength (X1)	Upper-limb force production expressed through repeated pushing actions relevant to throw-in mechanics.	Standardized push-up test; best score from three recorded trials after familiarization.	Repetitions
Hand flexibility (X2)	Wrist-hand range of motion available during controlled flexion and extension relevant to terminal release mechanics.	Goniometric wrist-hand mobility assessment; best score from three recorded trials.	Degrees
Throw-in performance (Y)	Distance achieved during a legal two-handed overhead football throw-in performed according to IFAB procedure.	Standardized throw-in distance test from the sideline; best distance recorded.	Meters

Data collection was completed across three supervised testing sessions to minimize fatigue and to preserve procedural consistency. Before each session, participants completed a standardized warm-up consisting of light jogging, dynamic mobility, and rehearsal movements specific to that day's test. The researcher and two physical education teachers jointly supervised the testing process. Participants first received verbal instructions and live demonstrations to standardize their understanding of the task. Two familiarization trials were then provided for each test so that the students could adapt to the procedures before official measurement began. After familiarization, three recorded trials were administered, and the best score was retained for analysis. For the throw-in test, students performed from a consistent sideline position, and distance was measured from the release line to the first point of ball-ground contact. For the push-up and flexibility tests, the same raters and the same instruments were used throughout the study. This procedure was intended to reduce avoidable measurement noise and to keep the results as comparable as possible across participants.

The measurement framework used to construct the dataset is presented in Table 1. Descriptive statistics were first calculated, including minimum, maximum, mean, and standard deviation for each variable. Pearson product-moment correlation was then used to estimate the bivariate relationship between arm muscle strength and throw-in performance and between hand flexibility and throw-in performance. A multiple-correlation procedure was applied to estimate the combined relationship of X1 and X2 with Y, and the corresponding coefficient of determination was used to express the proportion of explained variance. Statistical significance of the overall model was tested with the F statistic at alpha .05. Because the aim was explanatory rather than predictive in a machine-learning sense, emphasis was placed on the magnitude, direction, and interpretive meaning of the coefficients. Data screening focused on score plausibility, scoring consistency, and the expected linear direction of the relationships. The reported values were also interpreted in relation to the field-testing context and the practical demands of the football throw-in rather than as abstract statistical quantities alone.

Several steps were taken to strengthen methodological credibility. All measurements were obtained under the same field conditions, with the same instruments, and by the same test team throughout the study. Participants were informed about the purpose and procedures of the research before testing, and the confidentiality of personal data was maintained throughout the recording and reporting processes. Because the procedures consisted of routine, non-invasive school-based performance tests, the study posed minimal risk to participants. The emphasis on standardized administration was important because field-based measures are only useful when scoring criteria and instructions are tightly controlled. In this respect, the design sought to

balance ecological validity and practical feasibility with sufficient methodological rigor to support meaningful interpretation of the relationships among arm muscle strength, hand flexibility, and throw-in performance.

III.RESULTS

The analysis was conducted to determine the extent to which arm muscle strength and hand flexibility were related to throw-in performance in football. Descriptive statistics for the 30 participants are presented in Table 2. Arm muscle strength ranged from 12 to 30 correct push-up repetitions, with a mean of 21.3 and a standard deviation of 5.29. Hand flexibility ranged from 75 to 90 degrees, with a mean of 82.4 and a standard deviation of 4.68. Throw-in performance ranged from 10.1 m to 19.1 m, with a mean distance of 13.1 m and a standard deviation of 2.38 m. These values indicate that the sample contained meaningful variation across all three variables and therefore provided an adequate basis for correlational analysis. Table 2 also shows that none of the variables clustered around an unrealistically narrow band of scores, a pattern that would have weakened the interpretability of the resulting coefficients.

Table 2. Descriptive statistics of arm muscle strength, hand flexibility, and throw-in performance

Variable	Minimum	Maximum	Mean	Standard deviation
Arm muscle strength (X1)	12	30	21.3	5.29
Hand flexibility (X2)	75	90	82.4	4.68
Throw in performance (Y, m)	10.1	19.1	13.1	2.38

The dispersion profile shown in Table 2 suggests that participants were not concentrated within a single physical-performance profile. Arm muscle strength displayed the widest spread in relative terms, indicating substantial variation in upper-body capacity from one student to another. Flexibility was somewhat more compactly distributed, but it still varied enough to allow meaningful comparison. Throw-in distance also showed a clear range of performance, implying that the students differed not only in physical preparedness but also in the practical football skill under investigation. This pattern is important because correlational analysis becomes more informative when the sample reflects realistic field heterogeneity rather than tightly compressed scores. In practical terms, the descriptive findings imply that the students entered testing with noticeably different readiness levels in the physical capacities presumed to support the throw-in, which in turn made it possible to examine whether those differences aligned with throw distance.

Pairwise relationships among the variables are reported in Table 3. Arm muscle strength was very strongly and positively correlated with throw-in performance ($r = .932$). Using Fisher's z transformation for descriptive interval estimation, the 95% confidence interval for this coefficient extended from approximately .861 to .967, indicating that the relationship remained strong even at its lower plausible bound. Hand flexibility was likewise very strongly and positively correlated with throw-in performance ($r = .918$; 95% CI [.833, .961]). The arm-strength coefficient was therefore marginally larger, but both associations were clearly high in magnitude and positive in direction. In practical terms, students who completed more correct push-up repetitions and students who demonstrated greater wrist-hand range of motion tended to record longer throw-in distances. No negative or trivial association appeared in the correlation matrix, and the pattern was therefore consistent across both physical predictors.

Table 3. Correlation matrix among variables X1, X2, and Y

Variables	X1	X2	Y
Arm muscle strength (x1)	1.000	0.950	0.932
Hand flexibility (x2)	0.950	1.000	0.918
Throw-in performance (y)	0.932	0.918	1.000

Table 3 also shows that arm muscle strength and hand flexibility were themselves strongly related ($r = .950$; 95% CI [.897, .976]). This result indicates that the students with higher upper-body capacity also tended to show better mobility scores, suggesting that these physical qualities clustered within the sample rather than developing in complete independence. When both independent variables were entered simultaneously, the multiple correlation coefficient was $R = .938$, indicating a very strong combined relationship among arm muscle strength, hand flexibility, and throw-in performance. The corresponding coefficient of determination was $R^2 = .880$, with an adjusted R^2 of approximately .871, meaning that about 88% of the variance in throw-in distance was explained by the combined model. The F test yielded $F = 98.396$ at the .05 significance level, confirming that the overall relationship was statistically significant. Thus, the data support the conclusion that the two predictors jointly account for a substantial proportion of the observed variation in throw-in performance in this sample.

Correlation structure among study variables

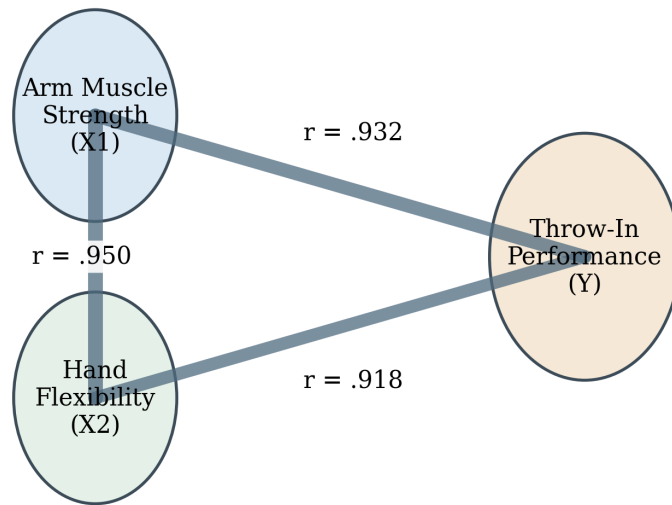


Figure 1. Correlation structure among arm muscle strength, hand flexibility, and throw-in performance

Figure 1 provides a visual summary of the correlation structure reported in Table 3. The thickest line appears between arm muscle strength and hand flexibility, while both variables also show strong positive links with throw-in performance. Visually, the diagram reinforces the numerical finding that the two predictors were not operating in isolation but were embedded in a common performance profile. Taken together, the descriptive statistics, the correlation matrix, and the model summary point to a consistent empirical pattern: longer throw-ins in this sample were associated with greater upper-limb strength and greater hand flexibility, both separately and in combination. The results section, therefore, establishes a clear quantitative basis for the broader biomechanical and pedagogical interpretation developed in the discussion section.

IV. DISCUSSION

Two findings define the present study. First, both arm muscle strength and hand flexibility showed very strong positive relationships with football throw-in distance. Second, the combined coefficient was only slightly higher than the strongest bivariate coefficient, which indicates that the most informative player profile is not strength alone or flexibility alone, but their integration. These findings fit the mechanics of overhead propulsion. A legal throw-in requires rapid force generation across the shoulder and elbow while the wrist-hand complex guides the ball during the final phase of release. When upper-limb force production is insufficient, release speed declines; when distal mobility is constrained, the release path and

quality can be limited. Linthorne and Everett (2006) showed that throw-in distance depends heavily on the speed-angle trade-off at release, while Radwan et al. (2024) reported that release velocity, release angle, and release height are central determinants of distance in football throw-ins. The present findings complement those kinematic observations by indicating that school-level variation in throw-in distance is strongly associated with the physical qualities that likely underpin those release variables. In other words, the differences observed among these students were not random technical variations alone but reflected measurable differences in the physical capacity available to execute the movement.

The stronger of the two bivariate coefficients was the association between arm muscle strength and throw-in performance ($r = .932$). This magnitude is consistent with the proposition that release speed is a decisive determinant of throw distance in a constrained overhead task. In youth and young adult populations, upper-body plyometric and resistance-oriented programs improve maximal strength and throwing-related performance, which provides indirect support for the present result (Garcia-Carrillo et al., 2023). Football-specific studies point in the same direction. Zainuddin et al. (2022) reported that push-up training improved standing throw-in distance, while more recent intervention studies using medicine-ball, resistance-band, and battle-rope exercises found meaningful gains in throw-in performance among youth football players (Humam et al., 2025; Siddik et al., 2025; Vieri et al., 2025). The current study does not establish causality, yet its correlational pattern helps explain why such interventions may work: athletes who can generate greater force through the arm and shoulder girdle appear better positioned to impart velocity to the ball. It is also important that the present participants were vocational students rather than elite academy players. In such a context, relatively simple field measures of upper-body capacity may capture a substantial share of the technical variation in throw-in distance, suggesting that school coaches do not need laboratory testing to identify players whose throw-in potential is physically constrained.

Hand flexibility also exhibited a very strong relationship with throw-in distance ($r = .918$), and this result deserves careful interpretation. In everyday coaching discourse, flexibility is often treated as a supportive trait secondary to power. Yet the throw-in is unusual because the final segment of the chain - the wrist-hand complex - shapes the effective release path under strict rule constraints. Greater wrist-hand range of motion may allow the player to preserve ball control, sustain a longer acceleration pathway, and release the ball with more favorable segmental alignment. This interpretation is consistent with Baihaqi and Wismanadi's observation that wrist flexibility contributes to the execution of projectile skills in basketball (Baihaqi & Wismanadi, 2020) and with the broader overhead-athlete literature showing that

mobility restrictions can alter terminal-segment mechanics and reduce efficient force transfer (Iida et al., 2025; Ramasamy et al., 2023). At the same time, the literature is not uniform. Telles et al. (2021) found that passive shoulder rotation range of motion was not directly associated with volleyball serve speed once age and body size were controlled. That contrast is theoretically useful because it suggests that the performance value of flexibility depends on the joint being measured, the task constraints, and the athletic population. Whereas passive shoulder rotation may not independently determine serve speed in trained volleyball players, distal wrist-hand mobility may be more directly involved in a legal two-handed football throw-in performed by adolescent school players. The present data, therefore, do not imply that more flexibility is always better; rather, they indicate that task-relevant mobility is meaningfully related to throw-in distance in this setting.

The most interesting statistical result may be that arm muscle strength and hand flexibility were not only individually related to performance but also strongly related to each other ($r = .950$) and together accounted for an overall multiple correlation of .938. This pattern has two implications. On the one hand, it suggests complementarity. Throw-in performance appears to be highest when upper-limb force production and distal mobility coexist, which aligns with current thinking on the overhead kinetic chain. Ellenbecker and Aoki (2020) and Jones and Safran (2024) argue that powerful overhead actions depend on synchrony across linked segments rather than isolated joint capacity. Ide et al. (2026) similarly showed that strength and range-of-motion measures become more informative when interpreted together because athletes do not perform with these qualities in isolation. On the other hand, the very high intercorrelation between the predictors warns against simplistic claims about their unique independent effects. Stronger students may also be those who are generally better trained, more mature, or more coordinated, all of which can be associated with higher mobility scores. For that reason, the present study is best read as identifying an integrated physical profile associated with effective throw-ins, not as assigning exact causal percentages to strength and flexibility separately. This more cautious interpretation is scientifically stronger because it reflects how physical qualities manifest in real players: clustered, interactive, and difficult to separate cleanly in school-based field settings.

The remaining 12% of unexplained variance is equally informative. Even a strong model left a modest portion of throw-in performance unaccounted for, indicating that other determinants remain important. Overhead sports reviews indicate that trunk stability, lower-limb power, hip-core coordination, and segmental sequencing can influence both performance and shoulder loading (Jones & Safran, 2024; Machado et al., 2023; Moiroux-Sahraoui et al.,

2024). In adolescent handball players, Bauer et al. (2022) found that better core-muscle endurance was associated with more favorable shoulder mobility-stability scores and, in part, with greater throwing velocity. These findings suggest that the throw-in should not be reduced to an arm-only action. Instead, arm strength and hand flexibility likely represent the distal expression of a broader kinetic system. This helps explain why some students with adequate push-up performance may still produce modest throw-ins if trunk timing, balance, or release coordination are suboptimal. It also explains why a field-based study such as the present one can yield strong but not exhaustive associations. The upper-limb variables measured here captured the most visible physical requirements of the skill, yet they inevitably condensed a larger biomechanical chain into two practical school-level indicators. Future studies that include hip-shoulder separation, trunk rotation, or lower-limb impulse would likely further refine the explanatory model.

The practical significance of these findings is amplified by the throw-in's contemporary tactical status. Performance analysis now indicates that throw-ins can act as micro-tactical devices for progression, retention, and chance creation rather than merely as neutral restarts (Casal et al., 2023; Kapelman et al., 2025). In the Indonesian context, the well-known example of Pratama Arhan has already shown how a long throw can become an offensive weapon when combined with organized movement around the penalty area (Kusuma et al., 2024). For physical education teachers and school coaches, the implication is clear: improving throw-in performance is not a cosmetic technical objective. It can increase functional game effectiveness. Because school programs often allocate limited time to set-piece detail, the throw-in offers an efficient instructional target for integrating technical rehearsal and physical conditioning. A short training block that combines repeated legal throw-ins with upper-body strengthening and wrist-hand mobility work may therefore yield immediate practical returns without displacing core football content. This is especially relevant in vocational schools, where training time may be narrower than in academy environments and where coaches need compact, evidence-informed interventions that fit the realities of school sport.

Training implications, however, should remain progressive and integrated rather than narrowly prescriptive. The present study does not justify the claim that more push-ups alone will maximize throw-in distance. What it does suggest is that upper-body conditioning deserves a regular place in football pedagogy. Review evidence indicates that youth players respond positively to strength, plyometric, and combined training even when they already participate in systematic football practice (Oliver et al., 2024). At the more specific level, upper-body plyometric training can improve throwing-related outcomes in young populations (Garcia-

Carrillo et al., 2023), while recent football studies report positive transfer from medicine-ball, resistance-band, battle-rope, and medicine-ball throwing exercises to throw-in performance (Humam et al., 2025; Santoso & Hakim, 2026; Siddik et al., 2025; Vieri et al., 2025). Accordingly, a sensible school-based program would combine three elements: first, age-appropriate upper-body strength exercises such as push-ups, partner-resisted throws, or light medicine-ball drills; second, mobility work focused on wrist-hand and shoulder range of motion; and third, repeated technical rehearsal under legal throw-in constraints. Such programming is likely to be more effective than isolated conditioning because it trains the athlete to express force through the actual skill. It may also help distribute load more efficiently across the kinetic chain, a principle emphasized in overhead-athlete injury-prevention literature (Moiroux-Sahraoui et al., 2024).

The results also have implications for school-based assessment and curriculum design. In many physical education settings, the throw-in is evaluated primarily for legal execution: both feet grounded, both hands on the ball, and correct overhead delivery. While these criteria are essential, the present findings indicate that performance quality is also shaped by trainable physical attributes. This matters pedagogically because students who struggle with throw-in distance may be judged only as technically weak when, in fact, they may also lack the upper-limb capacity or distal mobility needed to perform the task efficiently. The combination of Table 1, Table 2, Table 3, and Figure 1, therefore, has practical value beyond academic reporting. Together, they suggest a simple screening logic for teachers: determine whether the limitation appears predominantly strength-related, mobility-related, or likely linked to broader coordination factors. In curriculum terms, this supports a more integrated model of football instruction in which fitness development is not separated from technical learning but embedded within it. For vocational schools and similar educational institutions, such an approach can improve efficiency because a single structured training unit can address multiple outcomes simultaneously, including movement competence, game effectiveness, and student engagement.

A broader conceptual contribution of the study is that it reframes the throw-in as a developmental skill situated at the intersection of biomechanics and pedagogy. In many youth programs, set pieces are taught as fixed techniques to be copied, with limited attention to the physical resources required for technically correct execution. The present findings challenge that separation. By showing that strength and flexibility cluster together and correspond strongly with throw distance, the study supports a more ecological view of skill learning in which technique emerges from the interaction of instruction, physical capacity, and repeated task-specific practice. For practitioners, this means that improving throw-ins is not simply a

matter of correcting arm path or release timing. It also involves ensuring that learners have sufficient strength to accelerate the ball and sufficient mobility to express that strength through a legal, coordinated movement pattern. This perspective is especially useful in under-resourced school settings because it encourages coaches to use simple field measures as decision tools, thereby narrowing the gap between laboratory-informed sport science and everyday teaching practice.

Several limitations must nevertheless shape the interpretation of the study. The sample was small, male-only, and drawn from a single school, which limits external validity and may partly inflate correlation coefficients due to sample homogeneity. The design was cross-sectional, so causal direction cannot be inferred. The push-up test, while practical and defensible for school use, functions as a field proxy for upper-body strength-endurance rather than a direct measure of maximal arm force; prior evidence shows that push-up-based measures can be useful but are not perfect substitutes for criterion strength assessments (Baumgartner et al., 2002; Fernandez-Santos et al., 2016). Likewise, the flexibility measure captured wrist-hand range of motion in a practical manner, but it did not include shoulder, thoracic, or trunk mobility, all of which may affect throw-in mechanics. No kinematic, electromyographic, or force-platform data were collected, so the mechanisms linking the measured traits to performance remain inferential. The study also focused on distance rather than accuracy or match effectiveness, even though tactical utility depends on all three. These constraints should not be overlooked. Even so, the article makes a useful contribution by providing one of the few empirical examinations of throw-in performance in Indonesian adolescent footballers that simultaneously models strength and flexibility. It also shows that a field-based design can still yield conceptually meaningful sport science evidence when the research question is clearly aligned with practical coaching needs. In that sense, the work bridges laboratory-informed biomechanics and school-based physical education while offering a platform for larger, mixed-sex, longitudinal, or experimental studies in the future.

V. CONCLUSION

The findings of this study show that arm muscle strength and hand flexibility are strongly and significantly associated with football throw-in performance in male vocational students at SMK Negeri 1 Tenggarong Seberang. The bivariate coefficients were very high, and the combined model explained about 88% of the variance in throw-in distance, indicating that students who were stronger in the upper limbs and more mobile at the wrist-hand complex tended to produce longer legal throw-ins. The study therefore supports the view that throw-in performance is not

a minor or isolated technical skill, but a football action grounded in an integrated physical profile that combines force production and functional mobility. For school coaches and physical education teachers, the practical message is that throw-in instruction should be accompanied by structured upper-body conditioning and targeted mobility development rather than by technique rehearsal alone.

The study was limited by its single-school sample, male-only participants, field-based proxy measures, and cross-sectional design. Future research should examine larger and more diverse samples, include female athletes, and incorporate longitudinal interventions, motion analysis, force-based testing, and accuracy- or tactical-outcome measures. Even with those limitations, the present article contributes new evidence from an underrepresented Southeast Asian educational context and clarifies that arm strength and hand flexibility should be treated as complementary, not competing, components of throw-in performance. This contribution can inform curriculum design, school football coaching, and future biomechanical studies on youth player development.

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