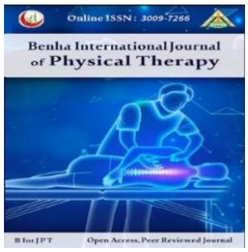
Benha International Journal of Physical Therapy

Online ISSN: 3009-7266 Home page: https://bijpt.journals.ekb.eg/



Original research

Relationship between trunk rotation and shoulder kinematics in colligate handball players: a pilot study

Mohamed F. Hebala[1], Sohier S. Rizkallah[2], Aya A. Khalil[3]

1.MSc candidate, Biomechanics department, Faculty of Physical Therapy, Cairo University, Egypt.
2.Professor Doctor of Physical Therapy, Basic Science Department, Faculty of Physical Therapy, Cairo University, Egypt.
3. Lecturer of Biomechanics, Biomechanics Department, Faculty of Physical Therapy, Cairo University, Egypt.

***Correspondence to**
Dr. Mohamed Fathy, *MSc candidate, Biomechanics department, Faculty of Physical Therapy, Cairo University, Egypt.*

E-mail: mohebala555@gmail.com

Article history:
Submitted: 1-4-2025
Revised: 17-4-2025
Accepted: 28-4-2025

Abstract

Background: Throwing motion is a sequence of movements generating in the lower quadrant to transfer energy toward the trunk and upper limb. Trunk plays the modulator role to transform moments into the upper limb. Disruption of one segment affects proximal and distal segments, and upper limb injury risk may increase. **Purpose:** The current study was designed to explore the relationship of trunk rotation and throwing arm kinematics. **Methods:** Ten healthy male handball players participated in the study. Each player's performance was analyzed using 3D motion technology. Data were collected using the semi-reality motion system. Pelvic-shoulder separation (amplitude of trunk rotation) and maximum shoulder external rotation (MER) were investigated for person correlation. **Results:** There was an insignificant correlation between pelvic-shoulder separation and maximum shoulder external rotation (P = 0.991).**Conclusion:** Our study results showed that trunk rotation angle was not correlated with throwing arm injuries in healthy collegiate handball players.

Keywords: Handball,Injury prevention, Performance analysis,Sports biomechanics.

Introduction

Throwing a handball is a widespread cause of musculoskeletal dis-orders, primarily injuries of the elbow and shoulders[1,2] ,Sports practice and performance have been significantly impacted by shoulder-related disorders among handball players[3] .According to handball-based research, shoulder pain prevalence ranged from 19 to 36% at the start of the season, and averaged roughly 28% per week.4,5 during throwing, a series of movements and moments must be generated in the lower quadrant before moving through the trunk and upper arm[6] .The moment of the following segments is increased by any disconnect in this sequence[7] .

Chain breakdown is caused by an improper sequence, which results in a loss of moment transfer from the trunk to the throwing limb[8] Inadequate segmental forces generation (relying on arm strength without using the lower extremities), incompetent motor patterns (scapular dyskinesia), or anatomical disorders (restricted shoulder range of motion) can all be accompanied by kinetic chain problems[9] .The feet, lower limbs, lumbo-pelvic region, trunk, scapulothoracic junction, shoulder and elbow, and distal forearm are among the kinetic series involved in throwing[8].

Please cite this article as follows: Hebala M, Rizkallah S, Khalil A,Relationship between trunk rotation and shoulder kinematics in colligate handball players: a pilot study.B Int J PT. 2025;3 (1):249-256. DOI:10.21608/BIJPT.2025.376719.1083

Both proximal and distal segments are impacted when one segment moves[9] .More forces can be generated by the more proximal segments (hips, core) while less forces applied to the more distal segments (shoulder, elbow, and wrist) when force transmission is efficient[7] .Significant lumbopelvic control is required as part of this kinetic chain in order to transfer forces generated in the lower extremities to the upper extremities via the trunk[6].

Radar[10], electromyography[11], and detailed video analysis[12] were the mainstays of early research on throwing diseases. The best current standard for performance analysis and injury prevention is represented by three-dimensional (3D) motion capture systems[13],However, athletes find it challenging to test such devices, process data, and understand results due to high costs, restricted availability, and the requirement for a team bio-mechanist to operate the system .

Current research on throwing focuses on capturing a large number of variables. For a known competitive level, key performance indicators (KPIs) are examined during the throwing phases. Higher upper limb loads and a higher risk of injury could result from improper throwing mechanics[14].

Throwing related upper limb injuries are common among collegiate athletes; this costs a lot of money for treatment and sometimes leads some young athletes with chronic recurring injuries to early retirement. Majority of similar studies have been done on baseballers. While less studies concerned with other throwing sports, and no similar studies investigated on the Egyptian handball population yet. Which represents the knowledge gap for our research. Therefore, the aim is to clarify the relationship between the throwing limb injuries and pelvic rotation, to set a preventive strategy to decrease injury rates among collegiate handballers.

Methods

The research ethics committee at Cairo University, Faculty of Physical Therapy in Egypt approved the study protocol (No: P.T. REC/ 012/ 004850). In January 2025, practical processes were carried out in Sports Science Laboratory, Faculty of Sports Education, Alexandria University, Egypt.

Study Design

Observational pilot study.

Participants

Ten male handball players from national handball teams in Alexandria offered their time to participate in the study. They signed a consent form and their personal data was collected**.** Each participant was evaluated for upper limb pain and dysfunctions, past medical history and screening with Arabic version of quick disability of arm, shoulder and hand scale (Quick DASH). Age ranged from 18 to 23 years, right-handed players, normal body mass index (BMI ranged from 19 to 24.9).

Exclusion Criteria

Excluded participants had; Previous shoulder dislocation, upper limb surgeries, lower extremity surgeries or acute trauma, other recent musculoskeletal disorders, recent upper limb pain or dysfunction.

Instrumentations

Instrumentation for Measurements:

The BMI was calculated using the health weight scale for height and weight measurements (BMI= weight (kg) / [height (m)] ^{2}).[15] Arabic version of the 19-items Quick DASH was used to determine pain severity.[16]

Instruments for three-dimensional (3D) motion capture:

Semi reality motion system (Semi) is a highly used 3D Marker-based motion capture technology (Semi Reality Motion Systems, GmbH, Germany) depending on a leading computer version and machine learning algorithms to detect and quantify movements in any condition**.** Semi system composed of 8 cameras [FUJINON 1:1.4/3.8-13mm, DV3.4x3.8SA-1 (100 frame/sec)] that can record and store images to pose estimation for automated full body or object 3D motion. A connected computer with (Semi motion 9.20 software) collects the captured data to store, sort, use, auto track, quantify and analyze the recorded movements.[17] All information and testing protocols are introduced through a keyboard into the computer's processing unit. The final results were provided in the form of testing data charts and graphs.

Assessment procedures

Calibration of the Semi system was performed according to the specifications outlined in the manufacturer's service manual. The X, Y, Z motion axes were identified as X is the direction of rotatory movements (medio-lateral), Y is the direction of (anterior-posterior) motion and Z represents the vertical direction **(Figure 1)**.

All participants were bare skin except for a tight black speedo swimming short. Forty-seven reflective markers were adjusted with a black double-faced tape to each player's land marks "Inverse dynamics" model of semi system.

Map markers included; Rt &Lt. acromion, sternum, xiphoid process, Rt &Lt. biceps belly, Rt &Lt. triceps belly, Rt &Lt. elbow medial epicondyle, Rt &Lt. elbow lateral epicondyle, Rt &Lt. wrist radial styloid process, Rt &Lt. wrist ulnar styloid process, Rt &Lt. hand third metacarpal, Rt &Lt. ASIS, Rt &Lt. hip greater trochanter, Rt &Lt. med-thigh, Rt &Lt. knee medial condyle, Rt &Lt. knee lateral condyle, Rt &Lt. mid-shank, Rt &Lt. ankle medial malleolus, Rt &Lt. ankle lateral malleolus, Rt &Lt. second metatarsal base, Rt &Lt. big toe, Rt &Lt. calcaneus, sacrum bone (S1), thoracic bone (T4), cervical bone (C7) and 4 markers for skull bone (medial and lateral frontal bone, medial and lateral temporal bone) **(Figure 2)**.

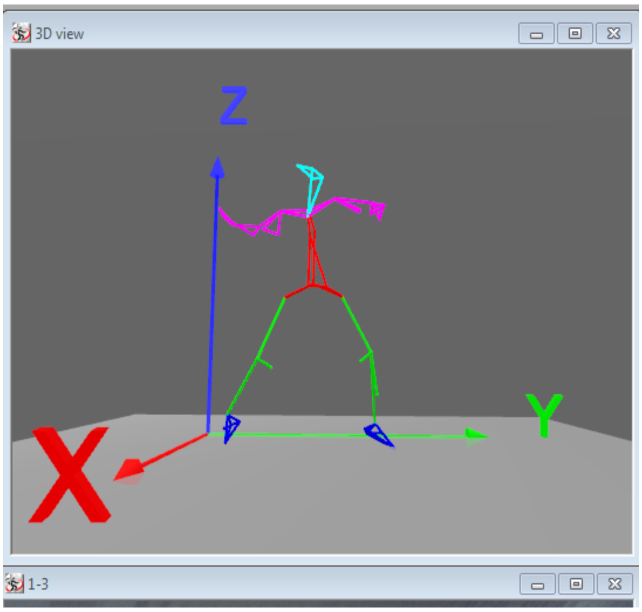


Figure 1: X, Y, Z axes identification

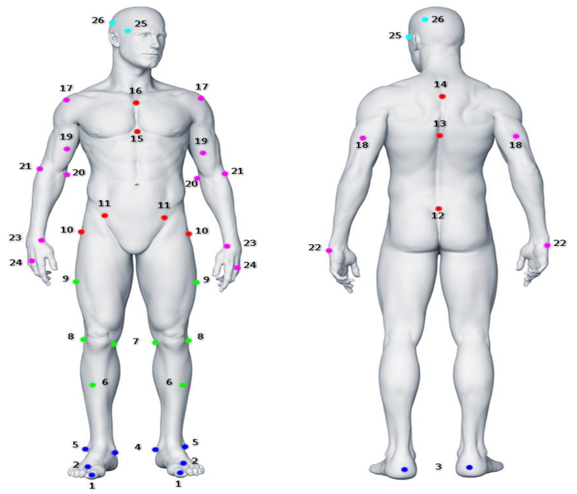


Figure 2: Inverse dynamics model for markers setup (A) anterior view & (B) posterior view.

The personal data, geometrical data, both hands grip-strength and Quick DASH score of each participant were introduced into computer. Brief instructions about the study process, its aims and the tests procedures to be accomplished were provided to each participant.

The participants were asked to perform 15 minutes warm up included; Vertical jump, push-ups and a series of upper quadrant flexibility exercises for body segments movements of trunk twist, shoulder horizontal abduction/ adduction and internal/ external rotation, elbow and wrist flexion/ extension[17].

Each participant was instructed to perform 3 throwing trials as hard and fast as possible, trying to turn their trunk at maximum velocity. One minute break was given between warming up and actual test sequence and between each throw. The most accurate trial (according to speed and precision) was recorded on the data register and analyzed for; the angle between pelvis segment and the Rt. upper arm at the moment of Lt. heel strike (Pelvic-shoulder separation), and maximum ext. rotation around the humerus longitudinal axis (Max. shoulder ext. rotation).

Statistical analysis

The Statistical Package for Social Science (SPSS) version 25 for Windows was used for all statistical calculations. Initially, data were screened by conducting Kolmogorov- Smirnov and Shapiro-Wilks normality tests for normality assumption as a prerequisite for parametric analysis. ($P \leq$ to 0.05) was considered significant. Pearson coefficient was conducted to reveal correlation between pelvic-shoulder separation and Max. shoulder ext. rotation.

Results

Demographic data of participants

Our 10 participants demographic data is shown in **(Table 1).**

Table 1: *Demographic data of participants*

	Mean	**Std. deviation**
Age (Year)	20.2	1.54919
Weight (Kg)	77.7200	7.68676
Height (M)	1.8120	0.05846
BMI (Kg/M^2)	23.5110	1.70554
Pelvic-shoulder separation (Degree)	39.6	11.91
Max. shoulder ext. rotation (Degree)	121.00	7.21

Correlation between pelvic-shoulder separation and Max. shoulder ext. rotation

Pearson coefficient revealed insignificant correlation between pelvic-shoulder separation and Max. shoulder ext. rotation (P= 0.991) **(Table 2)** and **(Figure 4).**

Table 2: Correlation between pelvic-shoulder separation and Max. shoulder ext. rotation in both groups

Mean ±SD	
Pelvic-shoulder separation	**Max. shoulder ext. rotation**
39.64±11.91	121.00±7.21
Correlation between Pelvic shoulder separation and Max shoulder external rotation	
Pearson correlation	0.004
P value	0.991

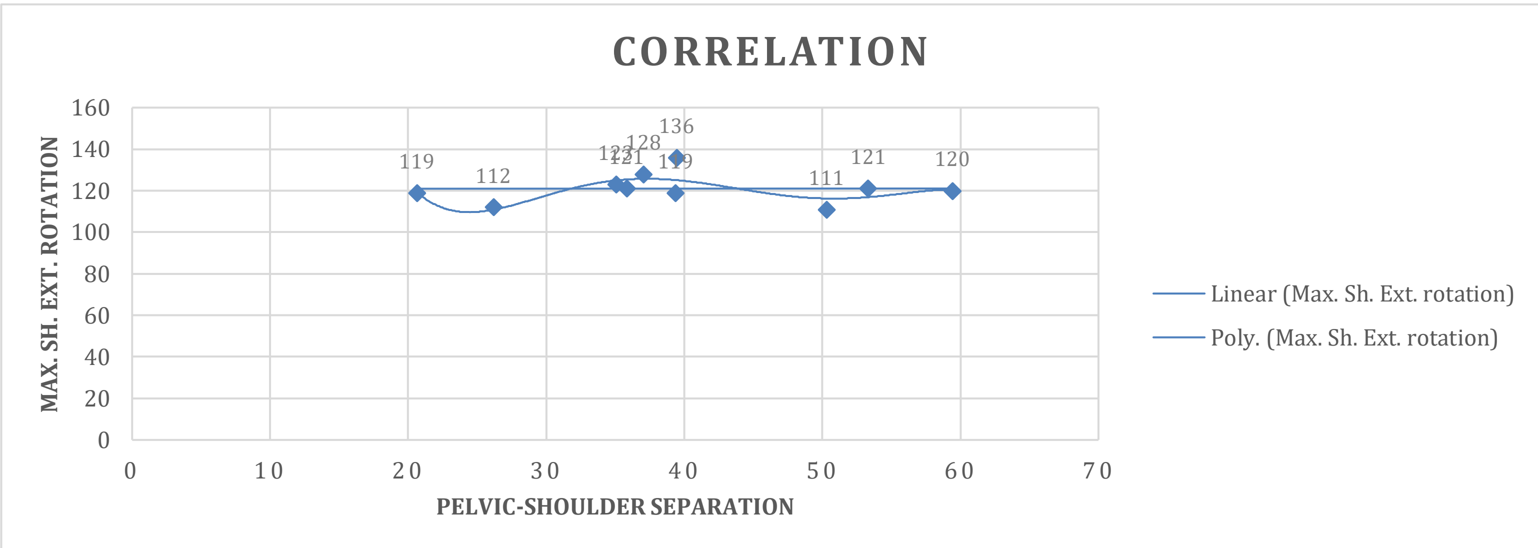


Figure 4: Correlation chart; X represents pelvic shoulder separation, and Y represents Maximum shoulder external rotation.

Discussion

This study investigated the relationship between pelvic-shoulder separation angle and shoulder external rotation in healthy colligate handball players. In this study, 10 male individuals were included. Each participants' performance was analyzed with 3D motion capture system to examine the hypothesized correlation. The present study showed insignificant correlation (P=0.991) between pelvic-shoulder separation and Max. shoulder ext. rotation in healthy colligate handball players.

The incidence of upper extremity injuries requiring surgery was found to be 33% with presence of early/insufficient trunk rotation.[18] According to Lin et al. (2022)[19], baseball players who do not rotate their trunks enough are at a significantly higher risk of undergoing elbow and shoulder surgery, with a hazard ratio estimate of 1.69.

Chalmers and colleagues (2017)[20] conducted a review of the relationship between throwing mechanics and upper limb injuries and found that fatigue, shoulder external rotation torque, trunk rotation, elbow varus torque, elbow flexion at ball release, and altered knee flexion at ball release were the most important risk factors. According to Keeley et al. (2015)[21]; stride length, lateral pelvic tilt at maximum shoulder external rotation, and the velocity of axial pelvic rotation at ball release are linked to 78% of the peak glenohumeral compressive force during the throwing motion.

When the quadriceps contracts to stabilize a fulcrum point, arm cocking starts with lead foot contact[22].The energy is then transferred from the pelvis to the upper torso as the pelvis rotates and the trunk extends[20] .Throwers who rotated their trunks before making contact with their stride legs and feet generated a notably higher elbow valgus torque[23] .According to van den Tillaar and Ettema (2004),[24] internal shoulder rotation and elbow extension account for 73% of the ball velocity and are the primary causes of over-arm throwing in team handball.

Shoulder pain is often experienced by athletes in the late cocking position, which prepares them for forward acceleration by having the arm maximally external rotated, the elbow 90° flexed, and the arm 90° abducted[25],When the upper extremity produces a powerful force and lowers the chance of injury[26].In this situation, shoulder pain may restrict the athlete's range of external rotation and prevent the ball from moving as quickly during the acceleration phase[27].Increased external rotational flexibility can help throwers perform better, but too much stretching can worsen capsule laxity and cause instability in the shoulder[25].

According to a prior electromyographic analysis of the shoulder muscles during throwing in 56 pitchers, the teres minor and latissimus dorsi muscles contracted concentrically during the cocking phase, increasing the shoulder's external rotation and resulting in an angular velocity of internal rotation of roughly 6500◦ per second.[28] Kinematic alterations linked to muscle fatigue from the throwing motion reduce tissue tolerance and raise the risk of injury[29].

In coaching, to improve athlete's performance, it is effective to follow a training cycle that includes understanding the structure of sports performance, setting goals and tasks, developing training plans to solve the problems, training the athletes, and evaluating/diagnosing their progress[30] .A recent review by Fredriksen et al. (2024)[31] examined the impact of particular strength training techniques and discovered that resistance band strength training exercises were the most efficient way to guarantee an increase in throwing velocity, aside from throwing underweighted balls.

According to Mascarin et al. (2017)[32], shoulder stabilization exercises utilizing elastic bands are essential for enhancing shooting speed and (ER/IR) ratios. Engaging the lower extremities during labral reconstructive surgery rehabilitation has been shown to activate the shoulder and scapula[9].

Our recent study disagreements with these previous studies might be explained as; these previous studies were mainly based on the analysis of baseball throwing pattern, while the current study concerned with handball stand throw pattern. The amplitude force generation and kinematic values differs for each pattern, each suited for game requirements. And the increased ball mass that needs to be taken into consideration could make team handball more difficult[33].

Due to financial constraints, this study only included a small sample size; it was self-funded, and the evaluation was conducted in a motion analysis lab rather than on a field or during a formal match, which did not accurately reflect the players' actual performance.

Suggestions for future research

Similar studies should perform sample size calculation to include larger sample. Future researches could investigate more kinematic variables like (elbow and lower limb kinematics) in an attempt to prevent injury. In addition, EMG and force plates could be used with the 3D motion capture to provide comprehensive analysis and draw a more detailed profile.

Conclusion

Our study results showed that trunk rotation was not correlated with throwing shoulder maximum external rotation angle in healthy colligate handball players. We recommend to repeat similar stud to include injured and non-injured athletes to allow for proper comparison.

Authors' contributions

M.F.H., S.S.R. and A.A.K.; methodology, M.F.H. and A.A.K.; software, M.F.H.; validation, S.S.R. and A.A.K.; formal analysis, M.F.H. and A.A.K.; investigation, M.F.H.; resources, M.F.H.; data curation, S.S.R. and A.A.K.; writing—original draft preparation, M.F.H.; writing, review, and editing, M.F.H., S.S.R. and A.A.K.; visualization, A.A.K.; supervision, S.S.R.; project administration, M.F.H.; financing acquisition, M.F.H. All authors had examined and approved this work's published version.

Availability of data and materials

After all authors have given their consent, the data gathered and examined during the study can be made available upon reasonable request.

References

1- Agel J, Rockwood T, Klossner D. Collegiate ACL Injury Rates Across 15 Sports: National Collegiate Athletic Association Injury Surveillance System Data Update (2004-2005 Through 2012-2013). Clin J Sport Med. 2016 Nov;26(6):518-523. doi: 10.1097/JSM.0000000000000290.

2- Bullock GS, Uhan J, Harriss EK, Arden NK, Filbay SR. The Relationship Between Baseball Participation and Health: A Systematic Scoping Review. J Orthop Sports Phys Ther. 2020 Feb;50(2):55-66. doi: 10.2519/jospt.2020.9281.

3- Hadjisavvas S, Efstathiou MA, Malliou V, Giannaki CD, Stefanakis M. Risk factors for shoulder injuries in handball: systematic review. BMC Sports Sci Med Rehabil. 2022 Dec 2;14(1):204. doi: 10.1186/s13102-022-00588-x.

4- Myklebust G, Hasslan L, Bahr R, Steffen K. High prevalence of shoulder pain among elite Norwegian female handball players. Scand J Med Sci Sports. 2013 Jun;23(3):288-94. doi: 10.1111/j.1600-0838.2011.01398. x.

5- Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: a prospective cohort study. Br J Sports Med. 2014 Sep;48(17):1327-33. doi: 10.1136/bjsports-2014-093702.

6- Laudner KG, Wong R, Meister K. The influence of lumbopelvic control on shoulder and elbow kinetics in elite baseball pitchers. J Shoulder Elbow Surg. 2019 Feb;28(2):330-334. doi: 10.1016/j.jse.2018.07.015.

7- Trasolini NA, Nicholson KF, Mylott J, Bullock GS, Hulburt TC, Waterman BR. Biomechanical Analysis of the Throwing Athlete and Its Impact on Return to Sport. Arthrosc Sports Med Rehabil. 2022 Jan 28;4(1): e83-e91. doi: 10.1016/j.asmr.2021.09.027.

8- Ellenbecker TS, Aoki R. Step by Step Guide to Understanding the Kinetic Chain Concept in the Overhead Athlete. Curr Rev Musculoskelet Med. 2020 Apr;13(2):155-163. doi: 10.1007/s12178-020-09615-1.

9- Kibler WB, Wilkes T, Sciascia A. Mechanics and pathomechanics in the overhead athlete. Clin Sports Med. 2013 Oct;32(4):637-51. doi: 10.1016/j.csm.2013.07.003.

10- Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med.

1995;23(2):233-239. doi:10.1177/036354659502300218.

11- Jobe FW, Tibone JE, Perry J, Moynes D. An EMG analysis of the shoulder in throwing and pitching. A preliminary report. Am J Sports Med. 1983 Jan-Feb;11(1):3-5. doi: 10.1177/036354658301100102.

12- Gainor BJ, Piotrowski G, Puhl J, Allen WC, Hagen R. The throw: biomechanics and acute injury. Am J Sports Med. 1980 Mar-Apr;8(2):114-8. doi: 10.1177/036354658000800210.

13- Manzi JE, Dennis E, Black GG, Trauger N, Quan T, McElheny KD, Dines JS. Kinematic and kinetic analyses of professional pitchers with history of core or groin injuries: A propensity-score matched analysis. J Orthop. 2022 Mar 1; 30:108-114. doi: 10.1016/j.jor.2022.02.025

14- Lin HT, Ko HT, Lee KC, Chen YC, Wang DC. The changes in shoulder rotation strength ratio for various shoulder positions and speeds in the scapular plane between baseball players and non-players. J Phys Ther Sci. 2015 May;27(5):1559-63. doi: 10.1589/jpts.27.1559.

15- Nuttall FQ. Body Mass Index: Obesity, BMI, and Health: A Critical Review. Nutr Today. 2015 May;50(3):117-128. doi: 10.1097/NT.0000000000000092.

16- Alnahdi AH. Validity and reliability of the Arabic quick disabilities of the arm, Shoulder and Hand (QuickDASH-Arabic). Musculoskelet Sci Pract. 2021 Jun; 53:102372. doi: 10.1016/j.msksp.2021.102372.

17- Akl A-R, Hassan I, Hassan A, Bishop P. Relationship between Kinematic Variables of Jump Throwing and Ball Velocity in Elite Handball Players. *Applied Sciences*. 2019; 9(16):3423. doi:10.3390/app9163423.

18- Douoguih WA, Dolce DL, Lincoln AE. Early Cocking Phase Mechanics and Upper Extremity Surgery Risk in Starting Professional Baseball Pitchers. Orthop J Sports Med. 2015 Apr 22;3(4):2325967115581594. doi: 10.1177/2325967115581594. Erratum in: Orthop J Sports Med. 2015 Jun 26;3(6):2325967115595220. doi: 10.1177/2325967115595220.

19- Lin YC, Lin HT, Lu CC, Pei-Hsi Chou P, Su FC. Is early trunk rotation really hazardous for shoulder biomechanics in baseball throwing? J Shoulder Elbow Surg. 2022 Jun;31(6):1282-1293. doi: 10.1016/j.jse.2021.12.042.

20- Chalmers PN, Wimmer MA, Verma NN, Cole BJ, Romeo AA, Cvetanovich GL, Pearl ML. The Relationship Between Pitching Mechanics and Injury: A Review of Current Concepts. Sports Health. 2017 May/Jun;9(3):216-221. doi: 10.1177/1941738116686545.

21- Keeley DW, Oliver GD, Dougherty CP, Torry MR. Lower body predictors of glenohumeral compressive force in high school baseball pitchers. J Appl Biomech. 2015 Jun;31(3):181-8. doi: 10.1123/jab.2011-0229.

22- Chorley J, Eccles RE, Scurfield A. Care of Shoulder Pain in the Overhead Athlete. Pediatr Ann. 2017 Mar 1;46(3): e112-e113. doi: 10.3928/19382359-20170216-01. PMID: 28287685.

23- Triplet JJ, Labott JR, Leland DP, Cheema A, Till SE, Kaufman KR, Camp CL. Factors that Increase Elbow Stress in the Throwing Athlete: A Systematic Review of Biomechanical and Motion Analysis Studies of Baseball Pitching and Throwing. Curr Rev Musculoskelet Med. 2023 Apr;16(4):115-122. doi: 10.1007/s12178-022-09800-4.

24- Van den Tillaar R, Ettema G. Effect of body size and gender in overarm throwing performance. Eur J Appl Physiol. 2004 Apr;91(4):413-8. doi: 10.1007/s00421-003-1019-8.

25- Mayes M, Salesky M, Lansdown DA. Throwing Injury Prevention Strategies with a Whole Kinetic Chain-Focused Approach. Curr Rev Musculoskelet Med. 2022 Apr;15(2):53-64. doi: 10.1007/s12178-022-09744-9.

26- Skejø SD, Møller M, Bencke J, Sørensen H. Shoulder kinematics and kinetics of team handball throwing: A scoping review. Hum Mov Sci. 2019 Apr; 64:203-212. doi: 10.1016/j.humov.2019.02.006.

27- Wilk KE, Obma P, Simpson CD, Cain EL, Dugas JR, Andrews JR. Shoulder injuries in the overhead athlete. J Orthop Sports Phys

Please cite this article as follows: Hebala M, Rizkallah S, Khalil A,Relationship between trunk rotation and shoulder kinematics in colligate handball players: a pilot study.B Int J PT. 2025;3 (1):249-256. DOI:10.21608/BIJPT.2025.376719.1083

Ther. 2009 Feb;39(2):38-54. doi: 10.2519/jospt.2009.2929.
28- Oliver G, Weimar W. Scapula Kinematics of Youth Baseball Players. J Hum Kinet. 2015 Dec 30; 49:47-54. doi: 10.1515/hukin-2015-0107.
29- Birfer R, Sonne MW, Holmes MW. Manifestations of muscle fatigue in baseball pitchers: a systematic review. PeerJ. 2019 Jul 29;7: e7390. doi: 10.7717/peerj.7390.
30- Demiral Ş, Nazıroğlu M. Examination of experienced coaches and physical education teachers' teaching methods and their perceptions regarding these methods-2023. Front Sports Act Living. 2024 Jun 3; 6:1383361. doi: 10.3389/fspor.2024.1383361
31- Fredriksen AB, van den Tillaar R. Effect of Six Weeks of Training with Wearable Resistance Attached to the Forearm on Throwing Kinematics, Strength, and Velocity in Female Handball Players. J Funct Morphol Kinesiol. 2025 Jan 24;10(1):45. doi: 10.3390/jfmk10010045.
32- Mascarin NC, de Lira CAB, Vancini RL, de Castro Pochini A, da Silva AC, Dos Santos Andrade M. Strength Training Using Elastic Bands: Improvement of Muscle Power and Throwing Performance in Young Female Handball Players. J Sport Rehabil. 2017 May;26(3):245-252. doi: 10.1123/jsr.2015-0153.
33- Plummer HA, Gascon SS, Oliver GD. Biomechanical Comparison of Three Perceived Effort Set Shots in Team Handball Players. J Strength Cond Res. 2017 Jan;31(1):80-87. doi: 10.1519/JSC.0000000000001475.

Please cite this article as follows: Hebala M, Rizkallah S, Khalil A,Relationship between trunk rotation and shoulder kinematics in colligate handball players: a pilot study.B Int J PT. 2025;3 (1):249-256. DOI:10.21608/BIJPT.2025.376719.1083