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Investigation Of Glenohumeral Internal Rotation Deficit Tendency of Adolescent Female Volleyball Players During Passive and Dynamic Movements

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Abstract

Objectives: This study aims determining the glenohumeral internal rotation deficit tendency of the competitor volleyball players non-invasively through measuring passive physiological and active range of motion of the shoulder joint during overhead movements. Twelve age matched adolescent female players (age of 17.6±0.4, BMI of 21.11±1.08 and height of 170.6±1.7cm) performed jump serve, strike of the ball, horizontal internal- external rotation and internal- external rotation movements and group-based data were analyzed. Bilateral kinematic data were collected from dominant and non-dominant shoulders with Xsens MVN. Each movement was performed five times and the average value was calculated for each participant. T-test paired sample results indicated that ROM did not vary during flexion (dominant: 170.2°±4.5; non-dominant: 171.3°±6.1; p=0.086) and Shoulder Horizontal External Rotation was not significantly different (dominant: 92.7°±4.1 non-dominant: 89.3°±6.3 p=0.052). Contrarily significant differences were obtained during Shoulder Horizontal Internal Rotation (dominant: 27.5°±8.3; non-dominant: 36.8°±7.9; p=0.0053), Shoulder Internal Rotation (dominant: 54.3°±9.0; non-dominant: 65.2°±11.2; p=0.0000) and Shoulder External Rotation (dominant: 98.6±2.5 non-dominant: 90.3°±6.36.7, p=0.0032). This study determined the differences between dominant and nondominant shoulders' passive ROM and investigated the dominant shoulder ROM during overhead movements by using an IMU based wearable motion caption system. The outcome of the investigation might be used as one of the practical and non-invasive early-detection techniques for GIRD tendency. Future research should determine if these findings are correlated with MR arthrographic imaging observations of posterior capsular thickening.

Keywords: shoulder, glenohumeral internal rotation deficit, jump serve, ball strike, Xsens MVN

Adolesan Bayan Voleybol Oyuncularının Pasif ve Dinamik Hareketler Sırasında Glenohumeral İç Rotasyon Eksikliği Eğilimlerinin İncelenmesi

Özet

Amaç: Bu çalışma, voleybol oyuncularının omuz ekleminin baş üstü hareketler sırasında pasif fizyolojik ve aktif hareket açıklığını ölçerek non-invaziv olarak glenohumeral iç rotasyon eksikliği eğilimini belirlemeyi amaçlamaktadır. On iki yaşça benzer adolesan kadın voleybol oyuncuları (yaş 17,6±0,4, VKİ 21,11±1,08 ve 170,6±1,7 cm boy) servis atışı, topa vuruş, yatay iç-dış rotasyon ve iç-dış rotasyon hareketleri grup bazlı uygulandı ve veriler analiz edildi. Bu deneysel çalışmada kinematik veri Xsens MVN ile baskın ve baskın olmayan omuzlardan topladı. Her hareket beş kez gerçekleştirildi ve her katılımcı için ortalama değer hesaplandı. Baskın ve baskın olmayan omuzdan kinematik veri ortalamaları t-testi kullanılarak kişi bazlı olarak analiz edildi. Sonuçlar omzun sagittal düzlem hareket eklem açıklığının (baskın: 170,2°±4,5; baskın olmayan: 171,3°±6,1; p=0,086) ve yatay dış rotasyonunun (baskın: 92.7°±4.1 baskın olmayan: 89.3°±6.3 p=0.052) baskın ve baskın olmayan omuzlar için istatiktiksel olarak farklı olmadığını gösterdi. Omuz Yatay İnternal Rotasyon (baskın: 27.5°±8.3; baskın olmayan: 36.8°±7.9; p=0.0053), Omuz İç Rotasyon (baskın: 54.3°±9.0; baskın olmayan: 65.2°±11.2; p=0.0000) ve Omuz Dış Rotasyonunda ise (baskın: 98.6±2.5 baskın olmayan: 90.3°±6.36.7, p=0.0032) istatiksel olarak anlamlı farklılıklar elde edildi. Bu çalışma, voleybol oyuncularının baş üstü hareketler sırasında baskın ve baskın olmayan omuzlarının pasif ve aktif eklem açıklıklarını belirledi ve IMU tabanlı bir giyilebilir hareket analizi sistemi kullanarak araştırdı. Araştırmanın sonuçları bu yöntemin GIRD yatkınlığının hızlı ve invaziv olmayan yöntemlerle erken teşhis edilmesinde kullanılabilecek yöntemlerden biri olabileceğini gösterdi. Bu bulguların arka kapsül kalınlaşmasının MR artrografik görüntüleme gözlemleriyle korele olup olmadığı ileriki çalışmalarda araştırılacaktır.

Anahtar Kelimeler: omuz, shoulder, Glenohumeral İç Rotasyon Eksikliği, zıplama servisi, top vuruşu, Xsens MVN

INTRODUCTION

The shoulder girdle has a primary function to position the upper extremity in space to allow the hand to perform its tasks. The coordinated and complex biomechanical interactions of the shoulder girdle structures allow functional movements in a wide range in three axes of motion that lie in the cardinal planes of the body. Upper extremity injuries are common in volleyball players due to the magnitude of the impact applied to the shoulder during overhead and throwing movements. This frequent force exposure causes chronic shoulder pain, sport- specific adaptations such as shoulder joint hypermobility, alterations in strength and flexibility that eventually results in upper extremity injuries such as rotator cuff injuries, scapula fractures and glenohumeral internal rotation deficit (GIRD) (5,9,11). In this population, the dominant shoulder develops gradual decrease in internal rotation, which is known as GIRD. GIRD is related to multiple factors such as osseous adaptation, musculotendinous and capsular tightness (2,3) that is defined as a loss of 20° and more of internal rotation compared to the non-dominant shoulder. Individuals with less than 18° of GIRD and corresponding symmetry of total range of motion within 5° of the non-dominant side are considered anatomic GIRD, while a pathological GIRD represents athletes with values beyond that amount (4,6,7,10,13,15,16,17-19).

Athletes with a pathological GIRD may be at high risk for possible shoulder injuries. Stiffness and decreased velocity during movement and pain at the shoulder are the major indications of GRID. As a result of these initial indications, volleyball players change their movement strategies and kinematic parameter unintentionally during overhead movements. This adaptation and hypermobility are unavoidable among volleyball players, therefore, early detection of this risk by using noninvasive, fast and practical methods is critical for this population.

Wilk et al. (12) demonstrated that pitchers with GIRD are almost twice as likely to be injured compared to those without GIRD. Additionally, they showed that pitchers with total rotational motion deficit of more than 5° had an increased injury rate. Recent studies indicated that volleyball and baseball players have GIRD on their dominant side with an average mean of approximately 10° for volleyball players and 20° for baseball players (8,12,14,16).

Wearable technology applications in healthcare can be defined as those products worn on the body of the user for specific period to collect physiological, biomechanical and cognitive information. This information can be investigated in real time or later. Wearable technologies have been widely used in healthcare for individualized self-care, early diagnosis, practical and timely data collection and disease management, therefore they significantly improve the efficiency of the treatment and help manage the disease. They facilitate easy and practical data collection in any setting; therefore, they do not require a lab environment. Wearable motion capture technologies are emerging devices that are frequently used in sports research. The athletes can perform their sportive activities and biomechanical, cognitive, and physiological data can be collected, analyzed, and evaluated anytime and anywhere. This advantage provides the natural environment for athletes from almost all sport branches.

The purpose of this study is to practically identify GIRD and examine the potential injury risk of competitor adolescent female volleyball players non-invasively by using a wearable motion capture system with the aim of potentially improving the performance of the athlete, reducing the injury risk, and guiding the coach to design and implement player-specific training and exercise programs. This study hypothesizes that GIRD leads to an increased risk for pathologic conditions of the shoulder and elbow in overhead athletes and kinematic data obtained during dynamic movements such as jump serve and strike of the ball will reveal the risk for potential injury through proposing a rapid and non-invasive methodology.

MATERIAL AND METHOD

Participants

Randomized controlled trial was carried out between January 2021 and March 2021. Dominant and non-dominant shoulder joint kinematic data during strike, flexion in the sagittal plane, Shoulder Horizontal Internal- External Rotation and Internal-External rotation of 12 competitor adolescent female volleyball players (age of 17.6±0.4, BMI of 21.11±1.08 and height of 170.6±1.7cm) who did not have orthopaedic surgery history and did not show any obvious postural abnormalities, collected. Determination of the sample size was done with G-Power (GPower - Universität Düsseldorf) version 3.2.1 and 12 participants satisfied 0.80 power ratio and 0.8 effect size (10% standard deviation, 95% accuracy rate (z=1.96)). Participants were excluded from the study if they reported neurologic, systemic, peripheral, or rheumatic pathologies, disease or injury that might affect the musculoskeletal system, any history of musculoskeletal injury in the past year, any type of surgery that may have affected the musculoskeletal system. With a sample size of 12, we had 95% confidence that the population mean would be within approximately ±5% of the sample mean. Each participant performed strength and conditioning exercises along with routine trainings twice a week during the competitive season and three times a week during the preseason. Trainings were planned and coordinated by the same volleyball coach for each participant. All participants followed strength training program during the season and preseason. The program focused on building lean body mass, increasing power and work capacity by improving volleyball-specific endurance. Prior to testing, each participant read and signed an informed consent that was approved by the Institutional Review Board.

Methods

Xsens MVN (Xsens Technologies BV®, The Netherlands) is a commercial, inertial sensor-based and portable motion capture system for full body motion analysis. Seventeen wireless sensors, (MTw2, range of measurement of angular velocity: ±1200 °/s, sampling rate: 100 Hz) which comprise accelerometer, gyroscope, and magnetometer, are attached to the key areas of the axial and appendicular body. Battery powered sensors communicate wirelessly with the host computer. Real time data is displayed on the main computer screen and this data is recorded for later analysis. The specially developed modular motion trackers detect all activities- from the smallest motion in the body to the dynamic motions. All types of motion are detected by the sensors, and the biomechanical data are collected and recorded in real time. Thanks to its wireless design, it provides a fast and easy installation and allows motion analysis to be done in the desired environment. Inertial sensors are useful in movement and balance cases with the advantage of their small size and portability that also made them popular recently with the advantage of suitability for use outside laboratory set-up. It allows an unrestricted, 3D and spontaneous gait analysis. The system allows spontaneous gait analysis and has been validated against optical motion capture systems (7, 10, 20). In these studies authors used optical based motion capture and Xsens MVN concurrently during various daily activities and investigated the validity and reliability of the biomechanical data collected. Results showed that wearable motion capture system successfully collected precise and accurate kinematic data. Zhang et al (2013) reported that during slow, normal and fast walking conditions, the Xsens system most accurately determined the flexion/extension joint angle (coefficient of multiple correlation > 0.96) for all joints when the results were compared with optical motion capture system. The system was used to collect kinematic data from participants.

A standard patient testing protocol was developed, and the same methodology was followed for each participant. The testing program included bilateral kinematic data collection during jump serve, strike of the ball, flexion in the sagittal plane, shoulder horizontal internal-external rotation and shoulder internal- external rotation from both dominant and non-dominant shoulder joints of the participants. Each movement performed five times and the average value was calculated for each participant. Each player performed 5 strikes from the middle of the court and the sideline. The ball was served to the player, passed to the setter and the strike was performed afterwards. All strikes during data collection were performed from the left side of the court. Data collection was performed over a single session while the participants were in sitting position and data were collected on the same day for each participant. All ROM measurements were performed within 2 hours. All subjects completed a demographic and patient characteristic form that included questions such as age, height, and weight.

Data processing and outcome measures

Twelve age matched healthy female competitor volleyball players' shoulder joint range of motion data for dominant and non-dominant upper extremity were collected during strike of the ball, jump serve, flexion in the sagittal plane, Shoulder Horizontal Internal- External Rotation (Shoulder at 90 degrees of abduction and elbow at 90 degrees of flexion) and Shoulder Internal- External Rotation (Shoulder at 90 degrees of abduction and elbow at 90 degrees of flexion) movements. Kinematic data were collected at 60 Hz with Xsens MVN wearable motion capture system. Spatial/temporal kinematic parameters were collected for both shoulder joints. Lengths of the body segments, using the landmark locations as references, were manually measured, along with subject height, weight, and foot length. MATLAB (The MathWorks, Inc. USA) was used for data analysis. The statistical analysis was performed using SPSS (version 12, Chicago, IL). All analyses used a confidence interval of 95% and a significance level of <0.05.

RESULTS

Twelve players completed the investigation. According to the results not a statistically significant difference was elicited within participants (mean: 152.4° ± 6.3 (Z = 2.51, p = 0.012) during strike of the ball movement. Strike kinematics is extremely complicated compared to the passive goniometric range of motion measurements. At ball contact moment, the trunk and the upper arm continue to alter trunk flexion; and at the same time shoulder and glenohumeral joint extension, scapular tilt, and horizontal adduction and internal rotation of the shoulder are observed. Hence isolated shoulder flexion during strike provides reduced glenohumeral movement capacity but the high velocity at the ball contact moment and the high impact that the whole body is exposed to causes glenohumeral instability and limited movement capacity of shoulder due to the tightening of posterior capsule. Similarly, maximum shoulder external rotation was 160.2° ± 2.6 (F (2, 9) = 2.787, p = 0.088) during jump serves and no significant difference was elicited among participants. Mean flexion values in the sagittal plane movement did not differ for dominant and non-dominant shoulders of the participants (Shoulder ROM: 170.2°±4.5 and 171.3°±6.1 respectively, p= 0.977 (p>0.05)). Mean Shoulder Horizontal Internal Rotation ROM values for dominant and non-dominant shoulders differed significantly (Shoulder Horizontal Internal Rotation ROM: 27.5°±8.3 and 36.8°±7.9 respectively, p=0.005 (p<0.05)). Correspondingly, Mean Shoulder Horizontal External Rotation ROM values for dominant and non-dominant shoulders did not differ significantly (ROM: 92.7°±4.1 and 89.3°±6.3 respectively, p= 0.052). Mean Internal rotation ROM values for dominant and non-dominant shoulders differed significantly (ROM: 54.3°±9.0and 65.2°±11.2 respectively, p=0.0011 (p<0.05)), similarly mean external rotation ROM values for dominant and non-dominant shoulders differed significantly (ROM: 98.6°±2.5 and 90.3°±6.36.7respectively, p=0.0011 (p<0.05)).

DISCUSSION

This study demonstrated that young female volleyball players present significantly different shoulder ROM, which is the expected result of and adaptation to frequent overhead movements, between dominant and non-dominant sides. This is the first study to present a nominal set of kinematic data -during a wide range of both static and dynamic activities- of adolescent, similarly experienced, female volleyball players. The aim was to propose a practical, timely and non-invasive early detection for GIRD tendency of competitor volleyball players.

This investigation presents both static anatomical and dynamic movements' kinematic data, which is collected in a volleyball court so that the movements of the players were not restricted due to the laboratory conditions. Passive goniometric investigation of both shoulders' ROM during internal and external rotation and the asymmetry between two extremities is the clinical approach for GIRD diagnosis. It is known from recent literature that overhead athletes present imperative adaptations in the glenohumeral joint due to repetitive and high impact shoulder movements, which cause eventual injuries in this joint (4,5,18). Our static measurements coincide with the most recent literature. However, this methodology fails in investigating GIRD during dynamic movements such as jump serve and strike of the ball. This investigation proposes an early prediction method for competitor volleyball players' GIRD tendency non-invasively and practically and most importantly rather than in a clinical setting, in athletes' natural settings. Hence, on time MR screening and specific training programs for the athletes, who have significant GIRD risk, might be planned to prevent potential injuries.

The relatively small sample size (n=12) is a limitation of this study. Nevertheless, small but significantly homogenous population- female adolescent competitor volleyball players, who have similar training apprenticeship- participated in this study. Additionally, this study did not obtain retrospective epidemiological information on previous injuries that the participants have experienced. However, we have excluded players who reported serious shoulder pain, fracture and/or surgery that limited the time of their practice over the past six months. Future research should determine if these findings are correlated with MR arthrographic imaging observations of posterior capsular thickening. Additionally, a complete set of overhead movements (float service and spike) will be added to the investigation.

The findings of the study clearly demonstrated that adolescent female volleyball players are prone to GIRD due to frequent overhead throws. Since overuse-related pathology often begins perniciously, it is important to utilize practical innovative engineering applications for identifying injury risk of the athletes. Pain and altered range of motion in shoulder joint is common among volleyball players (1). Limited range of motion is a clear parameter for impairment-risk analysis and performance evaluation. The findings indicate that even young players are prone to GIRD at the beginning of their careers, mature players should be consistently controlled to predict the injury risk and plan personalized, appropriate training and rehabilitation program for each player in a very practical and time efficient way. Therefore, the biomechanical parameters reported in this study are associated with potential injury risk and should be validated through prospective investigation.

TABLES

Table 1. Anthropometric parameters, age, and training apprenticeship of individual players

Player	Height (cm)	Weight (kg)	Training apprenticeship (years)
1	175	57	4
2	172	52	5
3	169	63	4
4	181	68	3
5	177	62	4
6	170	59	4
7	167	56	3
8	172	62	5
9	170	59	4
10	182	69	4
11	176	61	5
12	174	59	4
Mean ± SD	173.8 ± 4.7	60.6 ± 4.8	4.1 ± 0.7

Table 2: Passive and dynamic range of motion data of the dominant (hitting) and non-dominant (contralateral) shoulders in female adolescent volleyball players

Movements (n, 12)	Mean Dominant Shoulder Range of Motion (°)	Mean Non-Dominant Shoulder Range of Motion (°)	P value
Strike of the ball	152.4 ±6.3	n/a	n/a
Jump serve	160.2±2.6	n/a	n/a
Flexion in the sagittal plane	170.2±4.5	171.3±6.1	0.086
Shoulder Horizontal Internal Rotation	27.5±8.3	36.8±7.9	<0.05*
Shoulder Horizontal External Rotation	92.7±4.1	89.3±6.3	0.052
Shoulder Internal Rotation	54.3±9.0	65.2±11.2	<0.05*
	GIRD: 10.9°		
Shoulder External Rotation	98.6±2.5	90.3±6.36.7	<0.05*
	Increase in External Rotation: 8.3°		

Data are presented as mean ± standard deviation. *Significant difference between hitting and contralateral shoulders (P<0.05)

FIGURE CAPITONS

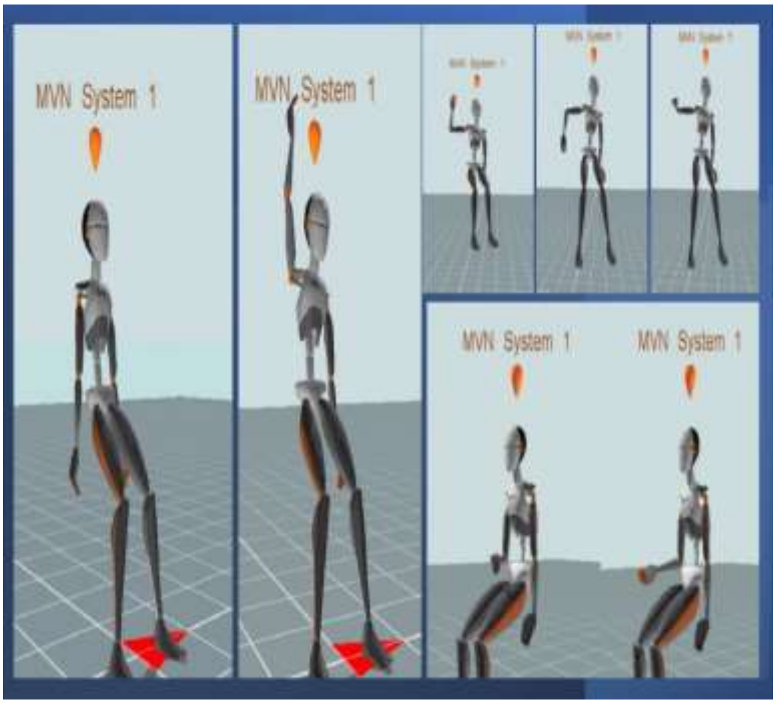

Figure 1. (1) Xsens MVN avatar demonstrating the

"flexion in the sagittal plane" movement (dominant arm): For flexion movement inspections subjects were asked to elevate their arms- with keeping the arm straight, lifting it forward and up, above their head as far as is comfortable. (2): Xsens MVN avatar demonstrating the "internal- external rotation" movement (dominant arm): For Internal rotation, participants were asked to rotate their arms inwards, still with the elbow at 90° flexion so that the flat of their hands touched the stomach if there is a full range of movement. (3): Xsens MVN avatar demonstrating the "Shoulder Horizontal Internal- External Rotation" movement (dominant arm): test participants were asked to slowly lower their arm -bent from their elbows- and do the opposite movement.

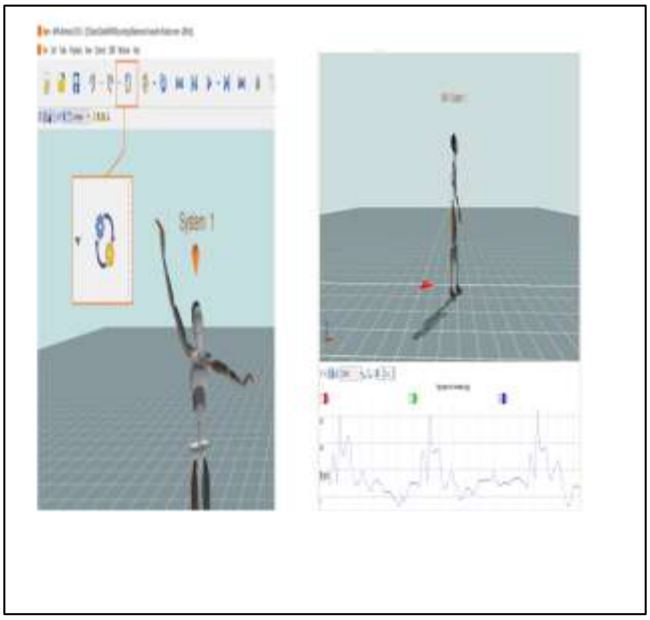

Figure 2. Shoulder motion during strike of the ball and jump serve

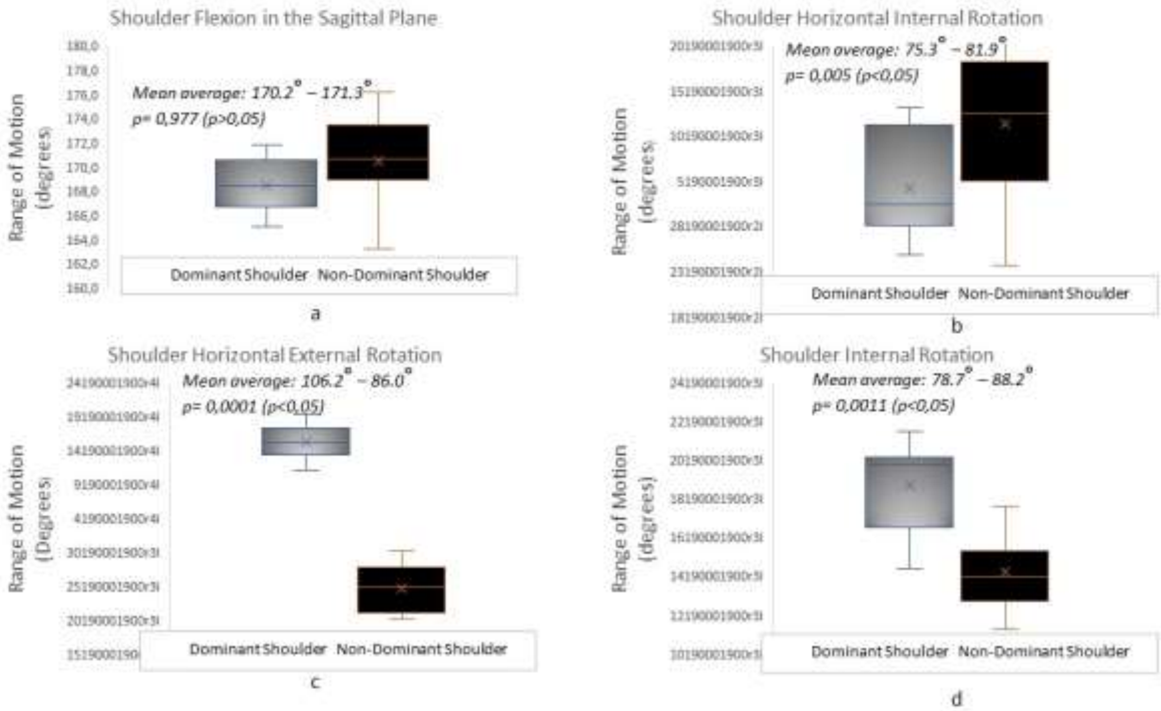

Figure 3. Shoulder Range of Motion during (1) Shoulder Flexion in the Sagittal Plane, (b) Shoulder Horizontal Internal Rotation (c) Shoulder Horizontal External Rotation (d) Shoulder Internal Rotation

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