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IMPROVING PREVENTION OF INJURIES OF ROTATOR CUFF SHOULDER JOINT IN THROWING ATHLETES. THEORETICAL APPROACH

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ABSTRACT

As a motor ability of the body, the overarm throw is a fundamental specific action that requires the development of qualitative kinematic possessions in the association of the limb segments that force the quantitative modification in movement technique and task effect. Appropriate throwing mechanism allows sportsmen to realise suprema performance with least chance of trauma, particularly in injuries of rotator cuff and labrum of shoulder joint. Purpose was to review biomechanics throwing performance and propose an improved prehabilitation program of athletes based on literature. Literate review was used with focusing on physiology and biomechanics of the throwing performance, muscle sliding filament theory description and proposed prehabilitation program for throwing athletes based on evidence. Eventually it was described 12-week training programme based on the principles of periodization and the aforementioned training principles. Goal of program was to prepare athlete participating in throwing activity for the high level competition in best performance condition, high throwing velocity and less risk of injuries.

KEYWORDS: shoulder, throwing, prehabilitation, biomechanics.

INTRODUCTION

As a motor ability of the body, the overarm throw is a fundamental specific action that requires the development of qualitative kinematic possessions in the association of the limb segments that force the quantitative modification in movement technique and task effect.[1]

Appropriate throwing mechanism allows sportsmen to realise suprema performance with least chance of trauma. Despite there are many types of throwing sports, it may be found general similarities among throwing disciplines too. One crucial property is the absorption of a kinetic chain to produce and transfer energy from the larger body parts to the smaller, to upper extremity with higher chance of injuries.[2]

Following general motions are involved in throwing kinetic chain (*Table 1*).

Table 1: Breakdown of throwing movement.

#	**Kinetic chain steps**
1	Stride
2	Pelvis rotation
3	Upper torso rotation
4	Shoulder internal rotation
5	Wrist flexion

Every joint rotates onward, consequent joint continues action and previous joint returns back into an elevated position. This sequence enables to stretch and eccentrically load the combined segments and muscles[2] *(Picture 1).*

Important moment is peak of external rotation of the shoulder in 180º. This is sum of glenohumeral rotation, body hyperextension and scapulothoracic motion. Right after maximal shoulder external rotation, both shoulder and elbow muscles eccentricallyconduct shoulder internal rotation and elbow varus torque. This extreme point is exposed by injury. At the end of discharge, most energy and momentum relocated to the thrown object and after that kinetic chain of shoulder and elbow musculature release huge concentric forces to resist joint distraction.[2]

In the table two, it is illustrated phases, kinetics and anatomy of joint actions (*Table 2*). Leading leg is maximally lifted and flexed in the wind up phase. Stance leg positioned stable with small slight flexion.[2]

Further during stride phase, lead leg moves anteriorly together with both arms starts to externally rotate. Crucial moment in this phase is scapular positioning in shoulder external rotation. Role of trapezius and serratus anterior is huge in this, improper positioning leads to impingement.[3]

In the arm cocking phase, external rotation is very important moment in further velocity generation in throwing. Thus, multiple attempts in throwing brings to shoulder capsule laxity and flexibility.[3] However overuse of laxity can lead to instability.[4]

In the last moment of arm cocking phase, m.triceps contracts eccentrically and m.anconeus to control flexion limit, unless in case of radial nerve impairment, flexion could reach 145°.[5]

It is crucial to extent elbow to reduce resistance of shoulder muscles to flex within longitudinal axis.[2] In the arm acceleration phase, stable and straightened knee of lead establishes strong base for trunk forward movement. Next action is arm abduction in 90° is remained whole acceleration phase in all disciplines. Further internal should rotation is acted by concentric work of anterior rotators to produce extreme velocity.[6] Consequently posterior cuff muscles controls and stabilise glenohumeral joint.

As long as elbow extents leading to maximum velocity, shoulder internal rotation continues with maximal velocity of whole arm before object release. However, more role plays centrifugal torque of the trunk-arm-elbow velocity.[7] Role of body segments in overall throwing velocity plays trunk in 75% during computer simulated study.[8] Wrist flexors rapidly contract (concentrically) to throw the ball by reduction of extension control of the wrist, as well as pronation adds some action.[9]

Consequently, leading arm horizontally adducts maximally in the arm deceleration phase. Shoulder back force and horizontal abduction torque stabilises arm from traumas.[10] Particularly, teres minor muscle place huge role in deceleration phase.[11] Resisting concentric forces in shoulder and elbow in release of object equals to whole body mass sometimes.[2]

In the follow through phase, enormous throwing generated force is absorbed by leading leg. Javelin throwing is almost similar to the ball by means of biomechanics. There is running phase before initiation of the stride. Running adds 5.6±0.7 m/sec and acceleration adds 3.1±0.9 m/sec to the linear velocity.[7] Also, javelin thrower has less elbow flexion in acceleration phase and less knee flexion. Velocity vector of javelin is 30º in horizontal plane.[13]

Possible pathological moments to be avoided by training

In the arm cocking phase, elbow flexes up to 90-100º and goes to valgus stressing ulnar collateral ligament, as well as pronator muscles of forearm. Due to weakness of pronator muscles, ligament could be overloaded. Further leading to ulnar bone stress with development of spur, irritating ulnar nerve. Eventually this brings to ulnar neuropathy. Varus torque during arm cocking phase leads to compression of soft tissues and avascular necrosis of radial-humeral joint.

In arm acceleration phase, extreme varus torque brings to wedging of olecranon and finally to formation of osteophytis.

Shoulder cuff tears are occurred usually from posterior side, as in acceleration and deceleration phase posterior compression forces induce impingement.[7]

During arm deceleration phase, grosser trochanter can impinge biceps, infraspinatus muscles under the acromion.[7] Quite often sports injury is SLAP lesion (superior labrum anteropoesterior). In the decenleration phase, long head of biceps produce compression and yanksdown labum leading to lesion.[12]

Purpose is to review biomechanics throwing performance and propose an improved prehabilitation program of athletes based on literature.

METHODS AND MATERIALS

Literature review was conducted at the resource centres of University College London (UK) and further enlarged at the Research centre of traumatology and orthopaedics (Uzbekistan) in 2019. Review focused on physiology and biomechanics of the throwing performance, muscle sliding filament theory description and proposed prehabilitation program for throwing athletes based on evidence.

RESULTS

Throwing biomechanics

Muscle groups involved in the throwing movement are included in the *table 3*.

Phase	Muscle groups
Wind up	Knee flexion
Stride	Viscoelastic energy restoration; Shoulderexternal rotation and abduction; Lead hip extension rotation; Stance leg hip internal rotation abduction; Wrist hyperextension; Lead elbow flexion, shoulder abduction, external rotation;
Arm cocking	Lead leg deceleration; Pelvic rotation and upper torso rotation;

	Scapular stabilization; Shoulder external rotation (180°); Shoulder internal rotation torque; Posterior cuff resist humeral head ant translation; Generate anterior shear force and horizontal adduction torque to resist posterior translation of the humerus/hold the arm moving forward; Elbow – varus torque resists valgus torque; Elbow – max flexion 100°; Elbow starts to extent;
Arm acceleration	Trunk flexes anteriorly; Lead leg stable and knee straighten; Shoulder internal rotation; Post cuff controls; Elbow extension; Arm internal rotation; Elbow flexion – declarative and stabilize joint; Wrist flexion and pronation;
Arm deceleration	Internal shoulder rotation; Full horizontal shoulder adduction; Shoulder posterior force to balance max adduction; Inferior force and adduction torque; Trunk flexion; Hip flexion; Lead knee compete extension; Lead elbow compete extension and elbow flex controls; Wrist extension; Wrist supination to resist pronation;
Follow-Through	Energy absorption; Shoulder posterior cuff forces; Scapular retraction; Wrist extension;

Main function of muscle is to transfer chemical energy to mechanical work plus heat using ATP. Each muscle covered by epimysium and comprises of smaller bundles called fascicles surrounded by sheets (perimysium). Moreover fascicles consisted of fibres covered with endomysium and tiny myofibrils combine fibre. Further myofibrils consisted of actin and myosin proteins. Actin and myosin moves through cross bridges using ATP and accomplishes contraction function.[14]

Motor control of the muscle is activated using functional motor unit – α motorneuron. Impulse transporting from cortex ends with production of acetylcholine leads to action potential with depolarization of the muscular membrane. Consequently, opened Ca^{+2} channels attaches troponin to myosin in order to activate cross bridges move actomyosin combination. Volume of Ca^{+2} and acetylcholine releases control motor function.[14]

Muscle physiology

Muscular strength is force produced within joint while utmost isometric contract. Power is a rate of generated force within velocity of contracted muscle. There are 3 types of movement are involved in muscle contractions. The force/velocity association is the reflexion that muscle force and contraction velocity are contrariwise interrelated. The velocity and force relationship is illustrated in *table 4* and *figure 1*.

Table 4: Muscle action velocity and force relationship.

#	Action	Force	Velocity
1.	Isometric		
2.	Eccentric – lengthening	High	High
3.	Concentric- shortening	High Low	Low High

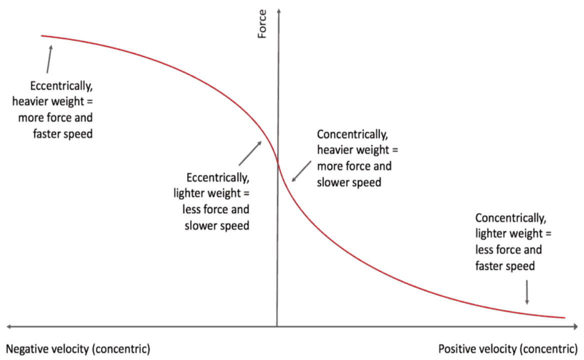

Figure 1: Chart of Muscle action (concentric and eccentric) velocity and force relationship (www.strengthandconditioningresearch.com)

According to the speed of contraction, fibre types are divided into 3 types (*Table 5*):

Table 5: Muscle fibre characteristics.

#	Muscle type	Speed	Resistance to fatigue	Mitochondria volume	Metabolism
1	Type I	Slow	High	High	Aerobic
2	Type IIa	Fast	Moderate	Moderate	Fast oxidative/Anaerobic
3	Type IIb	Fast	Low	Low	Anaerobic

Type I fibres expends less isometric force, slower in contract, however tolerated to fatigue. They have more mitochondria and tends to aerobic contrastingly type II fibres are faster and quick comes to fatigue.

Adaptation of organism to the exercises directed to resistance strength training and endurance training. During résistance training muscle overload sends impulses cortex to provoke muscle strength and mass.

Characteristics of the résistance strength and endurance training in the *Table 6*:

Sliding filament theory

A. F. Huxley and R. Niedergerke in 1954 described contraction of muscle. During contraction, there is a stable (A band) sarcomere of thick myosin and mobile (I band) filaments containing actin. Muscle contraction occurs after sliding actin over myosin.[16]

Length tension relationship

During muscle action, there occurs active and passive length tension relationships in terms of interaction between actin – myosin mechanism. Within active relationship, muscle shortened, while in passive one sarcomere stretches and elongates muscle (17). In the *figure 2, 3* we can see relationship.

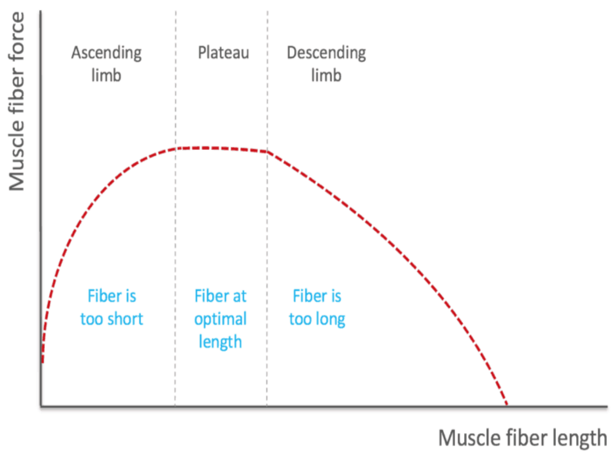

Figure2: active length-tension illustration (from www.strengthandconditioningresearch.com).

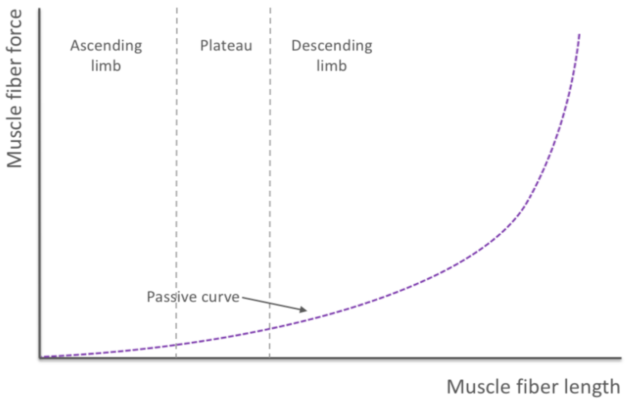

Figure3: Passive length-tension illustration.

Optimising the movement performance

It is crucial to optimise performance through conditioning both limbs including trunk, on condition that throwing comprises muscles of the knee, hip, trunk and shoulder joints. Weakness of any segment leads to maladaptive compensatory movements resulting failure or injury. Following authors recommended principles of better performance training principles **(*Table 7*):**

#	Author	Principle
1	Glenn S. Fleisig et al., 1996	Single joint exercises with loading; High speed multi joint exercises. Eccentric muscles involvement exercises.
2	Harridge S. et al., 1996	Endurance training – low load, more repetitions (fatigue resistance/aerobic metabolism); Strength training – high load, less repetitions (power, strength);

Main training characteristics are strength, power, hypertrophy, endurance. Variables are speed, agility, balance, coordination, jumping ability, flexibility.[15] Progression principles is described in the *Table 8.*

***Table 8: Progression principle description.*[18]**

1	Progressive overload	Gradual increase of stress on body during the training	a)Exercise intensity; b)Repetitions increased; c)Repetition speed/tempo; d)Rest shortened; e)Training volume;
2	Progressive specify	Specific physiological adaptations	a) contributed muscle action b) action speed; c) ROM; d) trained mus groups; e) energy sources; f) intensity/volume;
3	Progressive variation	Periodization – changing program types during RT, due to quick adaptation of body to one type of training[19]	a)Classical: from high volume+low intensity to low volume + high intensity(strength); b)Reverse classical: for endurance oriented; c) Undulating – variety modulations;

Further table is given general training characteristics[18](*Table 9*).

Injury prevention training programme

In the following outline, it is described 12-week training programme based on the principles of periodization and the aforementioned training principles.

Goal is to prepare athlete participating in throwing activity for the high level competition in best performance condition and high throwing velocity.

A 12-week training programme to be included in the appendix in sufficient details.

8 weeks of plyometric training may upsurge shoulder internalrotation power and throwing length.[20]Warm up with foam rollers is for self-myofascial release of the body is recommended according to Joseph A. Marsh and colleagues. [21] Strategy of strength training of the early stage consist of sports specific activities, muscular balance and recovery (adaptation) parts[22] There are discussions around plyo exercises, which improves strength more individual throwing sports rather than team games.[24]

Important function of coach is to evaluate capability of athlete and explain targets to the athlete. Targets need to be achievable, measurable (velocity of ball or length of distance thrown javelin).

For the early stage of the training (1st-4th weeks), following characteristics are included to the regime: loading - 30-60% 1RM, volume - 10 reps per set/2 sets per exercise, order - upper/lower split, rest - core - 2 min/supplementary-1 min., velocity – slow, frequency - 4 days (3 hours am/ 3 hours p/m) (*Table 9*).

In the mid part of the training loading raises up to 75%, velocity becomes moderate and 1 hour added to the frequency (*Table 10*).

Consequently loading raises up to 85%, velocity becomes fast, 12 reps per set/3 sets per exercise and 5th day is added for sport specific training in the late part of the protocol (*Table 11*).

Between each 4 weeks cycles it is beneficial to use doppler radar gun to measure throwing object velocity (ball, javelin).[23]

Table 9: Training program for throwing type of sports – early.

Week 1 – 4 Early stage: Low load		**Strength/power/endurance/sport specific/recovery**
Loading		30-60% 1RM
Volume		10 reps per set/2sets per exercise
Order		Upper/Lower split;
Rest		Core - 2 min/Supplementary-1 min;
Velocity		Slow;
Frequency		4 days (3 hours am/ 3 hours p/m)
Warm up		every day before exercise
Testing day		Friday
Dates	**Name of activity**	**Details**
Mon	Power Strength 30% 1RM	Olympic Lift (clean, snatch) Upper body static (bench, pull over) Lower body static (squat, deadlift)
Tues	Sport specific Endurance 40% 1RM	Throwing objects: Power throw drills/full throws Multi throws (med ball back, forward)

		Multi jump (stand hop, stand long jump) Short sprints (10 m stadium sprint)
Wen	General day 50% 1RM	Bodyweight exercise (core, MB circuits) Regional lifts (single joint rotator cuff/elbow) Core (med ball crunch, plank, reverse, boat balance) Plyo exercises;
Thur	Sport specific Endurance 60%	Throwing objects: Power throw drills/full throws Multi throws (med ball back, forward) Multi jump (stand hop, stand long jump) Short sprints (10 m stadium sprint)
Fri	Recovery	Hurdle mobility drills Self-myofascial release, foam rolling Swimming+cardio
Sat	Rest	Mental preparation
Sun	Rest	

Table 10: Training program for throwing type of sports – mid.

Week 5 – 8 Early stage: Intermediate load		**Strength/power/endurance/sport specific/recovery**
Loading Volume Order Rest Velocity Frequency Warm up		60 – 75% 1RM 10 reps per set/2 sets per exercise Upper/Lower split; Core - 2 min/Supplementary-1 min; Moderate; 4 days (4 hours am/ 3 hours p/m) every day before exercise
Dates	**Name of activity**	**Details**
Mon	Power Strength 60% 1RM	Olympic Lift (clean, snatch) Upper body static (bench, pull over) Lower body static (squat, deadlift)
Tues	Sport specific Endurance 60% 1RM	Throwing objects: Troubleshoot throw drills/throws Multi throws (med ball back, Gambetta shoulder crawl) Multi jump (stand hop, stand long jump) Short sprints (10 m stadium sprint)
Wen	General day 75% 1RM	Bodyweight exercise (core, MB circuits) Regional lifts (single joint rotator cuff/elbow) Core (med ball crunch, plank, reverse, boat balance) Plyo exercises;
Thur	Sport specific Endurance 70%	Throwing objects: Dry turn drills/full throws Multi throws (med ball back, Gambetta shoulder crawl); Multi jump (DB jump) Track sprints
Fri	Recovery	Hurdle mobility drills Self-myofascial release, foam rolling Swimming+Cardio Mental preparation
Sat	Rest	
Sun	Rest	

Table 11: Training program for throwing type of sports – late.

Week 9 – 12 Early stage: Intermediate load	**Strength/power/endurance/sport specific/recovery**
Loading Volume Order Rest Velocity Frequency	75 – 85% 1RM 12 reps per set/3 sets per exercise Upper/Lower split; Core - 2 min/Supplementary-1 min; Fast; 5 days (4 hours am/ 4 hours p/m)

Warm up		every day before exercise
Dates	**Name of activity**	**Details**
Mon	Power Strength 75% 1RM	Olympic Lift (clean, snatch) Upper body static (bench, pull over) Lower body static (one leg squats, deadlift)
Tues	Sport specific Endurance 80% 1RM	Throwing objects: Troubleshoot throw drills/throws Multi throws (med ball back, forward) Multi jump (stand hop, stand long jump) Short sprints (10 m stadium sprint)
Wen	General day 80% 1RM	Bodyweight exercise (core, MB circuits) Regional lifts (single joint rotator cuff/elbow) Core (med ball crunch, pull over, russian twist) Plyo exercises;
Thur	Sport specific Endurance 85% 1RM	Throwing objects: Dry turn drills/full throws Multi throws (med ball back, forward) Multi jump (DB jump) Track sprints/acceleration
Fri	Sport specific 85% 1RM	Light drill throw; Full throw; Multi throw; Low intensity throws Mental preparation
Sat	Rest	
Sun	Rest	

(1649 words)

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