Current concepts in thrower's shoulder: a South African perspective

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Abstract

The overhead throw is a fundamental movement utilised in numerous sports for a variety of reasons such as pitching in baseball, fielding in cricket, and passing or shooting in water polo. In the throwing athlete, the delicate balance of an external rotation gain (ERG) with a reciprocal glenohumeral internal rotation deficit (GIRD) while maintaining a 180° rotational arc is known as the thrower's paradox, described in baseball pitchers. This narrative review aimed to evaluate research findings and clinical experiences for two popular South African sports, namely cricket and water polo, to determine if these throwing athletes possess similar musculoskeletal and throwing characteristics classically described for baseball pitchers. Cricket and water polo players displayed distinctly different musculoskeletal characteristics to baseball pitchers. Cricketers did not present with the shoulder ERG frequently identified in throwing athletes, while water polo players did not demonstrate the decrease in internal rotation range commonly seen in throwers. A decreased external to internal rotation strength ratio (ER:IR) is a common risk factor in baseball pitchers. Cricketers and water polo players maintained a normal ER:IR ratio but presented with a decrease in both internal and external rotation strength. Finally, both cricketers and water polo players present with a downwardly rotated scapula at rest, which is contrary to previous findings in throwers. Water polo players had a significantly greater upward scapula rotation angle at 90°, which refutes subacromial internal impingement as a mechanism of injury in this group of overhead throwing athletes. Further differences are demonstrated in the throwing biomechanics of both sports, with cricketers using less shoulder external rotation and thoracolumbar range of motion while throwing compared to pitchers. Limited evidence found that water polo players use greater shoulder elevation than baseball pitchers or cricketers during shooting. While the literature documenting the types of shoulder pathology for cricketers and water polo players are scarce, there is clinical evidence that the different throwing athletes may present with a broad spectrum of shoulder injuries. In clinical practice, these insights can be used to enhance both the clinical assessment and management of overhead athletes.

Level of evidence: 4

Keywords: shoulder, throwing, biomechanics, musculoskeletal, risk factors, sports medicine

Introduction

The overhead throw is a fundamental movement utilised in numerous sports for a variety of reasons such as pitching in baseball,[1,2] fielding in cricket,[3,4] and passing or shooting in water polo[5,6] and handball.[7] In South Africa, cricket and water polo sports are popular and competitive sports across the ages.

Recent studies undertaken in South Africa investigating the kinematics and kinetics of the overhead throw in cricket,[4,8] as well as the musculoskeletal profiles of cricket[9] and water polo,[10,11] highlight distinct differences which challenge the applicability of the thrower's paradox described for baseball pitchers to other overhead throwing sports. To facilitate clinicians involved in the treatment of throwing shoulder injuries, this article explores the musculoskeletal profile, injury and associated risk factors, as well as the overhead throwing biomechanics of cricket and water polo athletes within a South African context.

To throw efficiently with speed and accuracy, the sequential coordination and harmonious muscular activation of the entire kinetic chain is required. Extant literature has determined that the legs generate 50–55% of the energy required to throw, providing humeral rotational velocity in excess of 7 000°/s and a resultant ball speed of approximately 136.8 km/h.[2] Further, the throwing cycle is completed in less than 0.145 s during baseball pitching[2] and 0.68–0.73 s when fielding in cricket.[4,8] Consequently, the overhead throw has been described 'as one of the fastest athletic gestures'.[12] The rapid nature and angular velocities achieved when repeatedly throwing overhead subjects the shoulder to significant stress and increased injury risk,[13] with 11.3–44% of overhead throwing athletes at risk of developing seasonal shoulder pain.[9,14,15]

The significant external rotation (ER) of the shoulder,[12] an adaptation commonly seen in the throwing shoulder, is associated with the thickening and contracture of the posteroinferior capsule, posterior band of the inferior glenohumeral ligament and posterior shoulder musculature (specifically teres minor, infraspinatus and deltoid), and is largely in response to the 750 N (1–1.5 times body weight) distraction forces imposed on the shoulder during the follow-through phase of throwing.[2,4,8] This musculoskeletal reaction is regarded as the 'essential lesion' which contributes to:

- An acquired loss of glenohumeral internal rotation, referred to as GIRD (where D stands for deficit): GIRD is defined as a difference in internal rotation (IR) range of movement (ROM) of greater than 18–20° between the dominant and non-dominant sides[16]
- Shifting the glenohumeral (GH) contact point posterosuperiorly, thus allowing for better clearance between the greater tuberosity and glenoid rim
- A reduced cam effect where the anterior capsule is no longer tightened by the humeral head[12]

The latter may further be enhanced by humeral retroversion.[17,18] Subsequently, the anterior capsule is subject to pseudo-lengthening as opposed to a truly increased laxity.[12] Overall, this delicate balance of an external rotation gain (ERG),[19] with a reciprocal GIRD, while maintaining a 180° rotational arc, is known as the thrower's paradox.[12,20] Immense uncertainty exists around when the thrower's paradox shifts from adaptative to pathological.

Musculoskeletal profile of the throwing athlete

While an increase in throwing shoulder external rotation range of motion (ER ROM) has been consistently associated with increased throwing velocity in baseball,[21-23] the benefits of the ERG with regard to loads on the shoulder joint have more recently been demonstrated.[24] An increased ER ROM of the dominant shoulder has been associated with lower loads on the shoulder and elbow when pitching.[24,25] Further, an asymmetry in the ER ROM of baseball pitchers with the greater ER ROM on the dominant side has also been associated with a decrease in joint torque and shoulder injury.[26,27]

Cricketers do not present with the thrower's paradox.[9] They do not have an ERG, have a greater reduction in internal rotation range of movement (IR ROM) compared to baseball pitchers, and have a reduced total rotational ROM.[9] The lack of ERG in elite, adult cricketers would seem to suggest that this group may not have had sufficient load during childhood and adolescence to promote the osseous and soft tissue adaptations seen in other overhead athletes and may increase the risk of injury in this population.

Water polo players are a more complex overhead throwing athlete as they are both a swimmer and a thrower. In addition, throwing and shooting are undertaken without the stable base afforded to land-based sports. Water polo players present consistently with a dominant ERG.[28-30] Elite water polo players have a unilateral GIRD – a decrease in IR ROM similar to baseball players – but have a bilateral increase in ER ROM frequently observed in swimmers.[30] Interestingly, no decrease in IR ROM has been observed in college or adolescent water polo players[10,11,29] (which would indicate that this acquired deficit in IR occurs later in water polo players than baseball pitchers).

GIRD does appear to be linked to shoulder pathology in overhead athletes, although it is unclear if it is a direct cause of injury.[16] A meta-analysis did not reveal any differences in GIRD for injured and un-injured youth and adolescent throwing athletes.[16] It remains unclear whether the apparent lack of GIRD in water polo players represents a delayed adaptation in water polo players' posterior capsule stiffness or that perhaps the swimming component of water polo may reduce the asymmetry in IR and neutralise this risk factor commonly observed in other throwers. It does suggest that water polo players, especially younger players, may have an increased or maintained total range of motion (TROM) which may influence the aetiology and treatment of a shoulder injury.

Typically, baseball pitchers display an increased IR strength with no concomitant increase in ER strength and hence a lowered ER:IR ratio.[24,31] Elite cricketers were found to have substantially reduced GH rotational strength for both IR and ER when compared to other overhead athletes,[19,32] and without significant asymmetry between sides with regard to rotational strength, and hence maintained ER:IR ratio.[32] Dominant shoulder GIRD has been associated with a decrease in total rotational ROM and poor shoulder strength in pitchers.[33] Similarly, the GIRD observed in cricketers, which is significantly greater than other overhead athletes,[9] may also partly explain the reduction in rotational strength observed in these throwing athletes.[19,32]

In adolescent water polo players in South Africa, studies report a range of findings in rotational strength. Jameson identified a general weakness in IR and ER with a maintained ER:IR ratio,[11] while Tully demonstrated a decrease in the ER:IR ratio largely attributed to a marked increase in IR strength.[10] Further the water polo players with the stronger dominant IR were more at risk of developing shoulder pain.[10] The rotational strength profile of water polo players is not uniform and differs between age-matched controls, different age groups and experience levels.[10,11,34-36] This further confirms a developing understanding that not all overhead athletes display the characteristics described for the classic thrower's shoulder.

Adequate upward scapular rotation (USR) has been shown to be important in preventing injury and maintaining optimal function of the upper extremity kinetic chain.[37,38] Traditionally overhead athletes have greater USR, and those athletes with less USR at 45° and 90° were more likely to develop shoulder pain.[39,40]

While baseball pitchers hold the dominant scapula in a small degree of upward rotation at rest,[19] elite cricketers demonstrated a more downwardly rotated scapula at rest until 90° abduction.[9] This contrasts with other overhead athletes who demonstrated an increased USR at these angles.[10,11,32,41,42] While the scapula position from rest to 90° is different for cricketers and baseball pitchers, both athletes had a similar degree of upward rotation at 120° of abduction.[19,32] Currently, the implications of these differences on both injury and performance are not clear.

Different to baseball norms, adolescent water polo players present with a downwardly rotated scapula at rest, which again achieves a similar angle of USR by 120°.[10,11] In a study evaluating injury risk factors in adolescent water polo players, injured players presented with an increased USR at all stages of upward rotation, but significantly greater USR at 90° of shoulder abduction,[11] invalidating subacromial or posteroinferior internal impingement as a possible cause of injury. This apparent lack of scapula control probably increases the load on the rotator cuff (RC) and is aggravated by a clinically weaker lower trapezius and serratus anterior in this group of injured water polo players. However, a further consideration may be that injured players attempt to avoid the pain of impingement by increasing the degree of USR above 90°. Further research is needed to fully explain this novel finding in water polo players.

There is significant variation in the musculoskeletal structural adaptations between throwing athletes in different sports, and the classic thrower's paradox is not an appropriate gold standard to apply to all throwers.

Biomechanics

Historically, the kinematic and kinetic analysis of overhead throwing has been conducted in baseball pitching,[2,43,44] with recent advancements in cricket[4,8] and water polo.[45-47] These latter studies challenge the philosophy that all throwing is performed in a similar manner by highlighting the distinct differences found in the fundamental demands of each sport.

In baseball, the luxury of time affords pitchers the opportunity to move through six distinct phases of throwing from a stationary position including the wind-up, stride, cocking, acceleration, deceleration and follow-through, during which the shoulder moves rapidly from a position of elevation and hyper-ER ('the slot') into maximum IR.[2,43,44] Consequently, the significant forces acting about the shoulder change from anterosuperiorly with compression at 'the slot' to posteroinferiorly with substantial distraction at maximum IR.[2,43,44]

In contrast to the static baseball pitch, cricket fielding requires the player to approach the ball from various angles and return it to the stumps as quickly as possible to limit the number of runs scored by the opposition or effect a run-out.[32] The cricketing throw is therefore characterised by a preparatory arc terminating at the cocking phase, as opposed to the wind-up and stride described in baseball.[32] Further, cricketers often throw from an unstable base of support with highly variable technique. Dutton et al.[4,8] found that cricketers threw with comparatively less shoulder ER and thoracolumbar flexion than baseball pitchers, and tended towards a sidearm (90–100° shoulder elevation[48]) rather than overhead throwing technique. The cricketer's shoulder experienced approximately double the forces exerted on the shoulder at cocking when throwing with a run-up approach compared to a stationary position (*Table I*). Further, the cricketing shoulder is subject to a posterosuperior directed force throughout the throwing motion, as opposed to the anterosuperior to posteroinferior forces observed during baseball pitching,[2,43,44] highlighting the potential development of an 'essential lesion'.[48] In the cricketer's shoulder, the absence of an ER gain,[3,4,8] combined with documented RC weakness,[32] may increase risk for injury.

The overhead pass and/or shot in water polo is also time-constrained and is performed off an unstable base. To compensate for the lack of hip and trunk power obtained easily during land-based throwing, water polo players utilise an egg-beater kick.[6,45-47] This motion elevates the torso out of the water, allowing the shoulder to extend, abduct and externally rotate, so that the ball is positioned high above and behind the head during the preparation or backswing phase of throwing. Cocking is characterised by horizontal abduction of the shoulder which then accelerates into IR and adduction during the forward swing. The latter phase is initiated by flexion of the hyperextended trunk to facilitate ball release speed. The throwing shoulder continues to decelerate and follow through in the direction of ball release.[6,45-47] While sparse, it is evident in the extant literature on the kinematic and kinetic analysis of overhead throwing in water polo that players utilise far greater shoulder elevation than both the land-based baseball pitchers and cricket

Table I: A comparison of shoulder ROM (°) and forces (N) at critical points in the throwing cycle for baseball pitching, cricket overhead throwing from a stationary position and following a run-up, and water polo overhead shooting/passing

	Baseball pitching [2,43,44]	Cricket [4,8]		Water polo [45-47]
		Stationary	Run-up approach	
Total throw cycle (s)	0.145	0.73 (0.18)	0.68 (0.15)	0.165 (0.022)–0.188 (0.024)
Maximum external rotation or 'the slot'				
Shoulder ROM (°)				
Elevation	94 (21)	91.2 (9.3)	92.4 (7.5)	115.1 (10.3)–123.8 (12.4)
Internal (+)/External (−) rotation	−175 (11)	−71.2 [−114.4 – −36.9]	−66.7 [−104.7 – 23.4]	−65 (11)
Force (N)				
Distraction (+)/Compression (−)	−480 (130)	−102.2 (30.8)	−129.3 (31.4)	−100*
Superior (+)/Inferior (−)	250 (80)	156.4 (77.3)	207.9 (94.7)	150*
Anterior (+)/Posterior (−)	380 (90)	−7.2 (14.1)	−21.8 (14.5)	120*
Ball release				
Shoulder ROM (°)				
Elevation	93 (10)	96.1 (6.4)	93.8 (7.3)	Unknown
Internal (+)/External (−) rotation	−64 (35)	−63.0 (42.4)	−51.9 (41.5)	−39 (16)
Force (N)				
Distraction (+)/Compression (−)	−1 090 (110)	−22.3 (26.4)	−4.4 (20.2)	−400*
Superior (+)/Inferior (−)	240 (80)	119.8 (64.5)	53.1 (48.8)	−100*
Anterior (+)/Posterior (−)	80 (180)	7.1 [−60.6 – 25.4]	6.6 [−29.2 – 31.3]	0*
Maximum internal rotation				
Shoulder ROM (°)				
Elevation	-	63.9 (16.9)	60.8 (17.1)	Unknown
Internal (+)/External (−) rotation	-	−15.0 (20.6)	−1.4 (24.2)	Unknown
Force (N)				
Distraction (+)/Compression (−)	1 100 (100)	61.4 (24.1)	68.6 (24.5)	Unknown
Superior (+)/Inferior (−)	−310 (80)	119.7 (35.4)	145.9 (37.7)	Unknown
Anterior (+)/Posterior (−)	−400 (90)	−62.2 (35.8)	−74.7 (30.6)	Unknown

*Approximate values provided; values expressed as mean (SD)

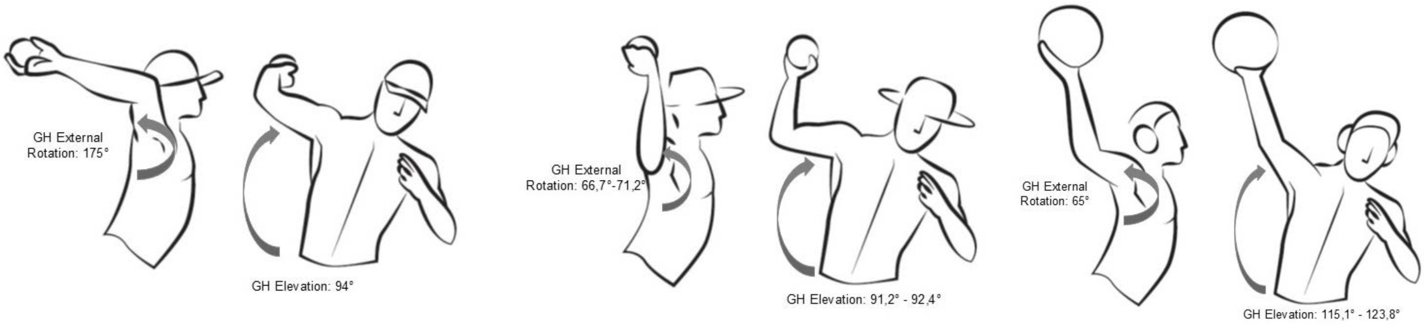

Figure 1. A sagittal and coronal plane visual representation of shoulder ROM (°) during cocking for a) baseball pitching, b) cricket overhead throwing, and c) water polo overhead shooting/passing
(Sketches are original, prepared for this manuscript.)

fielders at cocking (*Figure 1, Table I*), which may enable greater height out of the water to allow for arm clearance and additional leverage to generate throwing velocity. Water polo players present with an anterior shoulder force akin to baseball pitchers. This suggests that both baseball pitchers and water polo players may orientate themselves in greater thoracic rotation towards the throwing arm with increased horizontal abduction of the shoulder; as opposed to cricketers who are potentially more forward facing at this phase of the overhead throw. Finally, water polo players appear to release the ball with the greatest degree of shoulder IR (*Figure 1*) which may contribute to the substantial inferiorly directed force observed during arm deceleration with concurrent shoulder compression at ball release, potentially increasing the risk of injury to the shoulder labrum.

Injury profile of throwers

While there is clearly a difference between musculoskeletal profile and biomechanics in different throwing sports, it remains unclear whether these changes are represented in the types of pathology observed in the shoulders of these athletes. An additional confounder in the injury profile of water polo players is the contact nature of this throwing sport, which may result in acute labral and RC tears along with the more frequently reported overuse-type injuries.[49]

Despite considerable research and resultant interventions, shoulder injuries still account for 21−35% of all injuries sustained in professional baseball players.[50,51] Superior labral anteroposterior (SLAP) tears, caused by the peel-back mechanism of the biceps as described by Burkhart et al.,[37] is one of the most common injuries seen in baseball pitchers. Although this allows for increased ER and thus pitching speed, once a SLAP tear becomes symptomatic, it is one of the most devastating injuries seen in baseball pitchers. Acute tensile overload and/or repetitive microtrauma in the pitching action may lead to an articular-sided partial RC tear.[52] These tears are commonly more posterior than the traditional degenerative or traumatic tear, being situated at the junction between the posterior supraspinatus and anterior infraspinatus. Although uncommon, injuries to the latissimus dorsi, teres major, subscapularis and pectoralis major should not be overlooked as a cause of shoulder pain in these athletes. These less common injuries have been highlighted as a possible cause of poor return to play.[50,51]

The most common shoulder injuries reported in literature for cricketers are of the RC musculature and tendons.[53,54] In cricket players, an increased supraspinatus tendon thickness on ultrasound scan greater than 5.85 mm, in the dominant limb, has been identified as a predictor of an in-season injury.[32,55] This thickened RC tendon may be the result of a chronic overload of this tendon and may represent both a mechanism and source of pain among cricketers.

Shoulder injuries have been found to account for between 15 and 36% of all injuries in elite junior Australian and English cricketers, respectively; and 23–36% of all injuries in elite senior English cricketers.[56-58] In female cricketers, the shoulder is the most frequently injured anatomical site (3.7–31.4%).[59-61] In South Africa, shoulder injuries in elite South African cricketers have been reported in 18% of players over a single season at a rate of 0.19 injuries per player per year, and an annual injury prevalence of 1.1%.[32] Shoulder injury occurred primarily while throwing (58%), but diving for the ball, batting and bowling were also identified as the mechanisms of injury, which may explain the diversity of pathologies observed.[32]

Roche presented a spectrum of shoulder injuries in an instructional course lecture (2019) seen over a three-year period of documented shoulder pathology seen in professional and semi-professional cricketers.[62] These included intramuscular injuries of the pectoralis major and latissimus dorsi; tendon injuries of the supraspinatus and infraspinatus, proximal biceps, latissimus dorsi and pectoralis major; RC tendinosis; posterior labral tears; SLAP lesions; and coracoid stress fractures. Other shoulder pathologies identified included acromioclavicular (AC) joint arthritis, impingement and calcific tendonitis of the RC.[62] There is some commonality with injuries observed in pitchers but the spectrum of injuries reported among cricketers is a lot broader. Importantly, shoulder pain was also caused in some cases by pathology unrelated to a sporting injury.

Shoulder injuries in water polo players are reported in 24–51% of athletes.[63] Overuse injuries of the shoulder in water polo include swimmer's shoulder, RC pathologies and SLAP lesions.[64,65] The forceful and repetitive nature of swimming and overhead throwing in water polo can cause microtrauma in the RC muscles which may lead to RC impingement, tendinopathy or RC muscle tears.[64,66] SLAP lesions are found in water polo players as the superior labrum is placed under high distractive forces during the cocking and acceleration phase of throwing when the shoulder is abducted and externally rotated, and may lead to impingement of the labrum between the head of the humerus and the glenoid rim.[64]

An MRI study of water polo players demonstrated changes suggestive of internal impingement presenting as posterosuperior glenoid erosions, osteochondral defects, posterosuperior labral damage, and partial articular-sided RC tears.[67] These findings must be interpreted with caution as MRI findings are not always correlated with the clinical presentation in water polo players.[68] A 2018 review highlighted problems with the paucity of literature on the injury incidence, pathology, and injury definition.[63]

An increasing incidence of adolescent, school level, water polo athletes was observed in clinical practice. These patients presented with a diverse spectrum of shoulder pathology with a different pattern and distribution of injury when compared to reports from baseball literature.[49] A diverse spectrum of injury was seen when evaluating the MRI findings in the authors' orthopaedic practice (abstract accepted for the 2024 South Africa Orthopaedic Association Congress 2024, Cape Town, South Africa). A group of 34 symptomatic water polo players, under the age of 25 years, presenting with shoulder pain and who had MRI scans was identified. The five most common pathological findings were anterior labral tears (23%), posterior labral tears (19%), supraspinatus tendinosis (19%), SLAP lesions (19%) and paralabral cysts (16%). Eighty-six per cent of anterior labral tears, and 100% of posterior labral tears were associated with one or more additional pathological MRI findings. Only two (7%) scans out of a total of 31 were negative for any MRI abnormalities. This number of labral tears was unusually high, particularly as all patients were under 25 years of age. Additional injuries included lesser tuberosity avulsions, acromial apophysitis and coracoid stress fractures in a younger cohort of the players (< 18 years), which may relate to excess stress on immature skeletal structures.

The athletes that we commonly see participating in throwing sports in South Africa are water polo and cricket players; and less commonly those doing javelin, discus, shot put, netball and baseball. These sports all involve throwing projectiles of different weights and dimensions in different environments. A broad spectrum of pathology should be kept in mind when assessing the injured throwing athlete. Cricketers and water polo players share some typical pathologies with baseball pitchers but there are significant differences that clinicians must be aware of.

Conclusion and clinical implications

To facilitate clinicians involved in the treatment of throwing shoulder injuries, this article has explored the musculoskeletal profile, throwing biomechanics and injury profile of cricket and water polo athletes within a South African context using baseball literature as a reference. The nature of a narrative review may provide guidelines and suggestions but does not provide evidence at the level of a systematic review. Future research should be aimed at increasing the body of knowledge of these throwing sports to allow for a more robust review.

The following key points were identified:

- There is significant variation of musculoskeletal structural adaptations between throwing athletes; and the classic thrower's paradox is insufficient as a gold standard to apply to all throwers. Each overhead throwing athlete presents with a unique 'thrower's paradox'. Assumptions cannot be made with regard to musculoskeletal features of throwers, the examination, diagnosis or management of these patients. Generic treatment programmes cannot be applied across all throwing sports.
- The maintenance of total GH rotational ROM is imperative irrespective of ERG or GIRD. Clinical assessment of these parameters provides insight into the potential pathomechanics of shoulder injury in throwers.
- Shoulder rotational strength, both internal and external, differs between sporting codes. Assessing rotational strength provides insight into the pathomechanics and rehabilitation focus required in managing thrower's shoulder.
- Differences in scapula control – cricketers displayed a decreased scapular rotation and water polo players increased scapular rotation – may increase the load on the RC. Therefore, appropriate assessment of the scapula biomechanics, particularly USR between 90–120°, provides valuable insight.
- There is a lack of good quality studies reporting on the specific pathologies within the broader throwing population. Clinical observation reports a broad spectrum of pathology which extends far beyond the classic RC and labral injuries classically reported. Clinical awareness of this spectrum of injury may guide diagnosis and management.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. Ethics approval was not obtained (review article).

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

JG: study conceptualisation, first draft preparation, manuscript revision
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