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DESCRIPTIVE REPORT

Assessment of shoulder active range of motion in prone versus supine: a reliability and concurrent validity study

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Abstract

Background: As swimming and surfing are prone dominant sports, it would be more sport specific to assess shoulder active range of motion in this position. **Objectives:** To determine the reliability of the inclinometer and HALO[®] for assessing shoulder active range of motion in supine and prone and the concurrent validity of the HALO[®]. Concurrent validity is based on the comparison of the HALO[®] and inclinometer. To determine if active range of motion (AROM) differences exist between prone and supine when assessing shoulder internal (IR) and external rotation (ER). **Design:** The design included clinical measurement, reliability and validity. **Methods:** Thirty shoulders (mean age = 26.8 years) without pathology were evaluated. Measurements were taken in supine and prone with both an inclinometer and HALO[®] device. **Results:** Active ER ROM in prone was significantly higher than in supine when using both devices. Intra-rater reliability (within and between session) intraclass correlation coefficient (ICC) values ranged between 0.82–0.99 for both devices in supine and prone. An ICC test revealed a significant ($p < 0.01$) correlation for both devices in IR and ER movements ($ICC_{3,1} = 0.87$ and $ICC_{3,1} = 0.72$), respectively. **Conclusion:** This study has shown prone assessment of active ER and IR ROM to be a reliable and appropriate method for prone dominant athletes (swimmers and surfers). In this study greater ER ROM was achieved in prone compared to supine. This finding highlights the importance of standardizing the test position for initial and follow up assessments. Furthermore the HALO[®] and inclinometer have been shown to be reliable tools that show good concurrent validity.

Keywords

Inclinometer, prone, range of motion, reliability, shoulder

History

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Introduction

Physiotherapists routinely evaluate joint range of motion (ROM) as part of a musculoskeletal assessment (Riemann, Witt, and Davies, 2011). These measurements are critical in providing baseline measures, diagnosis of disorders and evaluation of treatment through quantifying degree of change (American Physical Therapy Association, 2003; Muir, Corea, and Beaupre, 2010). They are also routinely used in screening assessments for athletes to detect asymmetry, abnormality and potentially prevent future injury (Riemann, Witt, and Davies, 2011).

It is worthwhile to consider whether assessment of a joint can be carried out in a position that is relevant and specific for the athlete. Researchers are currently screening the shoulder in both recreational and competitive surfers. Meir, Lowdon, and Davie (1991) performed a time motion analysis of one hour of recreational surfing and found that 50% of the time is spent paddling in the prone position, therefore exploration of a prone shoulder AROM assessment was justified.

Shoulder injuries in a surfing population have been reported in previous literature, (Furness et al, 2014; Meir, Zhou, Gilleard, and Coutts, 2012; Nathanson, Haynes, and Galanis, 2002; Taylor et al, 2004) however, at present there are no studies which have evaluated joint ROM in this cohort. The current paucity of

research which physically assesses shoulder active ROM in a surfing population and the need to perform this in a prone position was the premise for this study. Prior to undertaking physical assessment of the shoulder in a surfing population, a reliable procedure in the prone position needed to be established.

Altered internal (IR) and external rotation (ER) has been associated with the etiology of shoulder disorders (Lin and Yang, 2006; Lunden, Muffenbier, Giveans, and Cieminski, 2010). Both of these movements are critical when in the prone position during surfing and therefore were the movements which needed to be examined. These movements can be objectively measured through a number of instruments including a ruler, tape measure, goniometer and inclinometer (Clarkson, 2005). Inclinometer appears superior to other devices as it can be calibrated on the basis of the universal constant of gravity. This enables the starting position to be consistently identified and repeated (Lea and Gerhardt, 1995).

The movement of shoulder IR and ER can be performed actively or passively; however active range of motion (AROM) is considered more reliable as this does not rely on the capability of the clinician to determine an end feel (Muir, Corea, and Beaupre, 2010).

An electronic search was undertaken to investigate methodology for assessment of active shoulder ROM for the movements of IR and ER in the prone and supine position. The following databases MEDLINE, CINAHL and EMBASE were searched using the primary search terms (shoulder, range of motion and all

synonyms for reliability). Only two research papers were identified which assessed shoulder range of motion in prone (Kolber and Hanney, 2012; Kolber, Saltzman, Beekhuizen, and Cheng, 2009). Both papers assessed shoulder IR in the prone position, however, ER was not assessed in the prone position. To our knowledge, there is no available research investigating shoulder ER in prone and the reliability of this movement for use in clinical assessment is yet to be established. Additionally although research exists which examines prone or supine shoulder IR, the methodology, device and sample population provide too many challenges to compare their results.

The absence of data for shoulder ER in prone developed the hypothesis that differences in ROM would be present when compared to supine. This has been previously demonstrated in the hip joint where significant differences existed when comparing mean ER values in sitting versus prone (36 degrees SD 7° versus 45 degrees SD 10°) (Simoneau, Hoenig, Lepley, and Papanek, 1998).

Recently a new commercial device known as a HALO© digital goniometer is available for clinicians to assess ROM. The HALO© uses a magnetic system for movements in the horizontal plane and accelerometers in the sagittal plane. Two lasers are situated on either side of the HALO©; this allows specific landmarks to be intersected and ensure correct and repeatable positioning. This device also has a vertical zero mode which ensures a consistent starting position similar to an inclinometer. To our knowledge no published literature exists which has investigated the reliability or validity of this device.

Therefore, three key aims were identified: (1) to determine within session and between session intra-rater reliability of the Inclinometer and HALO©, for the movements of shoulder IR and ER in the supine and prone positions; (2) to determine whether a ROM difference exists for IR and ER in prone versus supine; and (3) to determine the concurrent validity of the HALO© device.

Methods

Subjects

Testing was completed on both the dominant and the non-dominant arm; 30 shoulders in total (15 subjects) were tested and the data analyzed accordingly to determine within and between session intra-rater reliability. A sample size of 15–20 is often used in reliability studies, however, 30 or greater is required to form practically useful 95% smallest real differences (SRD) (Lexell and Downham, 2005). A total of 40 shoulders (20 subjects) were assessed to determine differences in prone versus supine. Demographic and background information was obtained on all participants; this included age, arm dominance and injury history. Subjects were eligible for the study if they were between the ages of 18–75 and able to adopt the starting position (90° of shoulder abduction). The study was approved by the Bond University Ethics committee (RO1610) and informed consent was gained from all participants.

Exclusion criteria included any acute or chronic shoulder pathology that may be aggravated or worsened through repeated testing of IR and ER. Based upon these aforementioned criteria, no participants were excluded. Participants were between the ages of 22 and 48 years with the mean age being 26.8 (SD 6.5) years.

Raters

The evaluators were two registered physiotherapists, one with seven years of clinical experience in the assessment and treatment of orthopedic conditions and the other a new graduate physiotherapist. Data collection began in January 2014 and concluded in February 2014 and was performed at a local university.



Figure 1. HALO© device.

The new graduate performed all measurements and the other physiotherapist recorded; this was done to ensure blinding occurred throughout all measurements.

Equipment

Inclinometer

A standard gravity-dependent inclinometer (Universal Inclinometer, model UI01, Performance Attainment Associates, Lindstrom, MN) was used for all range of motion measurements. To ensure the gravity dependent inclinometer was set to an accurate zero starting point, a vertical reference was established through the use of a bubble level. This reference point was then used throughout all testing.

HALO©

The HALO© (model HG1, HALO© Medical Devices, Australia) device was used for all joint range of motion measures in this study (Figure 1). This device has a “vertical zero mode”, where vertical is zero°. Therefore even if the shoulder is starting in a slightly internally rotated position this movement is accounted for. To our knowledge, there is currently no available research investigating the reliability and validity of this device in measuring joint range of motion.

Goniometer

A standard 12 inch, double armed 360 degree goniometer (JAMAR, E-Z Read, Seoul, South Korea) was used to establish a standardized patient set-up. The goniometer was used to ensure each movement was started from 90° of abduction.

Design

The two evaluators participated in a one hour formal training session with a musculoskeletal specialist to ensure correct measuring procedures were followed; this was done prior to data collection. Subjects were provided with verbal instructions and performed the required movement three times as a warm-up under the guidance of the assessors. This was completed to minimize the risk of a learning effect. This procedure was standardized for all testing and we believe offered no mobilization effect.

Active shoulder IR and ER rotation was assessed by two devices: (1) an inclinometer; and (2) HALO© in two different positions (prone and supine) consistent with the established protocols from Clarkson (2005) (Figure 2). An assessor positioned the subject and instructed the movement to be performed and a recorder then read and recorded the joint range of motion ensuring blinding of the assessor. Throughout all testing, the HALO© was used in the “vertical zero mode”. The gravity



Figure 2. Set-up for active IR and ER in prone and supine. (A) IR in supine with the HALO device; (B) ER in supine with the inclinometer; (C) ER in prone with the HALO device; (D) IR in prone with the inclinometer.

dependent inclinometer was re-calibrated between each change in position. Details of the test positions, manual stabilization and device placement are found in Appendix.

Each participant presented on two sessions on the same day for testing. The two sessions were separated by a time period of three hours and subjects were instructed to avoid any stretching or exercise during this time period.

Data analysis

Data analysis was performed with SPSS version 20.0 (IBM, Armonk, NY). Descriptive statistics including means, standard deviations and ranges were calculated for each measure and for each session. The intraclass correlation coefficient (ICC) was used to determine reliability (Lexell and Downham, 2005). Fleiss (1986) recommended that ICC values >0.75 represent “excellent reliability” and values between 0.40 – 0.70 represent “fair to good reliability”. A two-way mixed model were used to determine reliability between measure one and measure two within the same session ($ICC_{3,1}$). The between-session reliability was determined between the average of two measures from each session ($ICC_{3,2}$). This model was used because only the chief investigator was the tester of interest. ICC values may be high despite poor trial to trial consistency if the inter-subject variability is too high (Lexell and Downham, 2005). To negate this issue the standard error of measurement (SEM) was used as this is not affected by inter-subject variability. The SEM was calculated using the formula $SEM = \sqrt{WMS}$, where WMS is the mean square error term from the ANOVA (Hopkins, 2000; Lexell and Downham, 2005).

The smallest real difference (SRD_{95}) was also calculated to determine the magnitude of change that would exceed the threshold of measurement error at the 95% confidence level. The formula used was $SRD = 1.96 \times SEM \times \sqrt{2}$ (Safrit and Wood, 1989). Paired t-tests were used to determine whether significant differences existed between both shoulder IR and ER in prone versus supine. Intraclass correlation coefficient (ICC) was used to determine the correlation for both devices in IR and ER movements. Linear regression was performed for both devices in IR and ER movements to calculate R squared strength of relationship.

Results

A total of 30 shoulders were assessed (15 subjects, 8 males, 7 females) to determine the reliability of both devices in prone and supine. The overall mean age was 26.8 years (SD 6.5) range

Table 1. Within session reliability analysis.

			ICC ^(average)	95% CI of ICC	SEM	SRD
Prone	Inclinometer	ER	0.98	0.95–0.99	1.5	4.2
		IR	0.99	0.98–0.99	1.5	4.2
	HALO	ER	0.97	0.95–0.99	1.9	5.3
		IR	0.99	0.97–0.99	2.0	5.3
Supine	Inclinometer	ER	0.93	0.86–0.97	2.4	6.7
		IR	0.98	0.96–0.99	1.8	5.0
	HALO	ER	0.97	0.93–0.99	2.4	6.7
		IR	0.98	0.94–0.99	2.2	6.1

SD = standard deviation; ICC = intraclass correlation coefficient; SEM = standard error of measurement; SRD = smallest real difference at the 95% confidence level; IR = internal rotation; ER = external rotation.

22 to 48 years. Table 1 presents the within session reliability analysis with ICC values, SEM and SRD calculated. ICC values ranged between 0.93 – 0.99 and were all within excellent reliability ranges (>0.75) (Fleiss, 1986). The SEM and SRD values for the inclinometer in the prone position revealed lower values compared to the HALO© in prone.

Table 2 presents the between session reliability analysis with ICC, SEM and SRD values calculated. Lower ICC values (0.82 – 0.96) are represented compared to Table 1, however, they all are still with the excellent range. The SEM and SRD values are lower for the inclinometer in both positions compared to the HALO©.

Bland Altman plots for the prone position using the inclinometer present between session intra-rater values for ER and IR (Figures 3 and 4). The differences between measurements from the two test occasions are plotted against the mean of the two test occasions for each shoulder measured; the 95% confidence intervals are also included. Both Figures 3 and 4 reveal an unbiased agreement between session one and two for both ER and IR in the prone position.

Prone versus supine

A total of 40 shoulders (20 subjects, 12 males and 8 females) were assessed to determine if differences exist between prone and supine. The mean age was 26.4 years (SD 5.8) range 22 to 48 years. Table 3 presents the mean of measure one and two for session one in both prone and supine positions. ER in prone was significantly higher ($t = 3.0$, $p < 0.005$) than in supine (89.7° SD

Table 2. Between session reliability analysis.

			ICC ^(average)	95% CI	SEM	SRD
Prone	Inclinometer	ER	0.82	0.63–0.91	3.5°	9.7
		IR	0.96	0.91–0.98	3.4°	9.4
	HALO	ER	0.85	0.69–0.93	4.2°	11.6
		IR	0.96	0.92–0.98	3.3°	9.2
Supine	Inclinometer	ER	0.88	0.74–0.94	3.2°	8.9
		IR	0.96	0.91–0.98	2.7°	7.5
	HALO	ER	0.93	0.85–0.97	3.7°	10.3
		IR	0.84	0.66–0.92	5.8°	16.1

SD = standard deviation; ICC = intraclass correlation coefficient; SEM = standard error of measurement; SRD = smallest real difference at the 95% confidence level; IR = internal rotation; ER = external rotation.

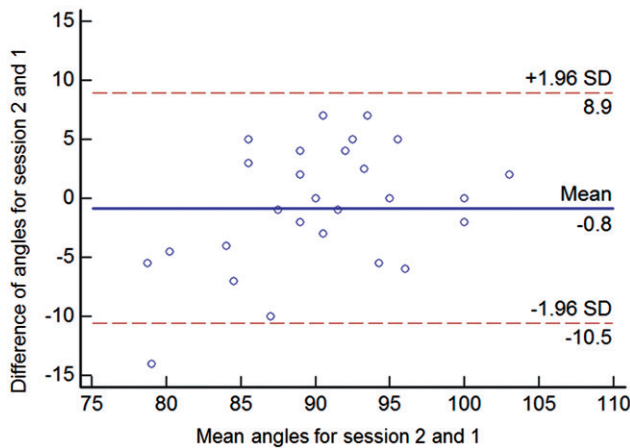


Figure 3. Bland–Altman plot for between-session reliability for prone ER with the inclinometer.

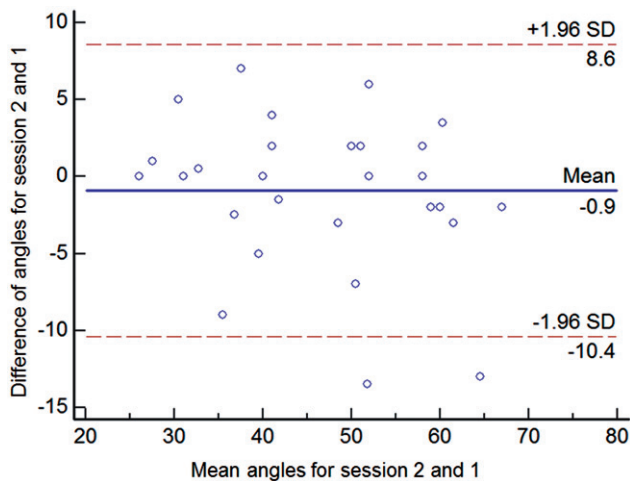


Figure 4. Bland–Altman plot for between-session reliability for prone IR with the inclinometer.

7.2° versus 85.4° SD 6.4°) when using an inclinometer. This was also the case for the HALO© device where ER in prone was significantly higher ($t = 2.4, p < 0.02$) than in supine ($89.2° \pm 8.6°$ vs. $85.1° \pm 10.0°$). IR with the inclinometer and HALO© device did not reveal significant differences despite a change in position.

To determine the level of agreement all data obtained for ER in prone were compared against ER in supine; the differences between individual data sets were analyzed using a One-Sample t -test. The results revealed a mean difference of 3.1° between the

Table 3. A comparison of mean scores for prone versus supine from session 1.

		Prone: mean (SD)	Supine: mean (SD)	Significant difference ($p \leq 0.05$)
Inclinometer	ER	89.7° (7.2°)	85.4° (6.4°)	0.005*
	IR	46.7° (11.4°)	46.9° (9.6°)	0.94
HALO	ER	89.2° (8.6°)	85.1° (10.0°)	0.02*
	IR	47.7° (11.7°)	48.2° (10.3°)	0.81

*Indicates statistical significance (< 0.05).

two test positions which was statistically significant ($p < 0.01$); this indicates the lack of agreement between the two test positions for ER. This is assuming that the null hypothesis would result in a mean difference of zero. The same procedure was conducted for IR with a mean difference of $-0.33°$ which was statistically insignificant ($p = 0.82$) indicating agreement between the two test positions for IR. A regression analysis revealed no significant bias ($p = 0.20$) in the distribution of data points either side of the mean difference for IR.

Concurrent validity of HALO© device

Concurrent validity was based on the comparison of the HALO and inclinometer. All ICC values for within session and between sessions were within excellent ranges (> 0.75) in prone and supine. A correlational analysis was therefore performed regardless of position. This analysis took the combined average from both sessions and both positions and compared the values from the inclinometer against the HALO©. Intraclass correlation coefficient (ICC) revealed a significant ($p < 0.01$) correlation for both devices in IR and ER movements ($ICC_{3,1} = 0.87$ and $ICC_{3,1} = 0.72$, respectively). The squared correlation coefficient (r^2) for ER was 0.35 and IR 0.59 indicating a stronger relationship for IR for the two devices (Figures 5 and 6).

Discussion

While several clinical measurements are available to measure shoulder ROM, goniometry and inclinometers remain the most widely used (Roy and Esculier, 2011). Previous research has assessed active shoulder IR and ER using an inclinometer (Green, Buchbinder, Forbes, and Bellamy, 1998; Hoving et al, 2002; Kolber and Hanney, 2012; Kolber, Saltzman, Beekhuizen, and Cheng, 2009). Two of these papers used a prone position however this was performed for IR only (Kolber and Hanney, 2012; Kolber, Saltzman, Beekhuizen, and Cheng, 2009). To our knowledge no paper has compared IR and ER in prone and supine. It would seem more logical to assess prone dominant athletes such as surfers in the prone position as this is specific to the sport.

The initial aim was to determine the reliability of both the HALO© and inclinometer. With regards to the inclinometer this current study revealed excellent within session (ICC 0.93–0.99) and between session reliability (ICC 0.82–0.96). Previous research (Green, Buchbinder, Forbes, and Bellamy, 1998; Hoving et al, 2002; Kolber and Hanney, 2012; Kolber, Saltzman, Beekhuizen, and Cheng, 2009) assessing reliability of inclinometry for shoulder active range of motion has reported varied results with ICC values ranging from 0.32–0.99. This current study’s findings exceed previous research by both Green, Buchbinder, Forbes, and Bellamy (1998) (ICC 0.75–0.82) and Hoving et al. (2002) (ICC 0.32–0.43) and are comparable to results by (Kolber, Saltzman, Beekhuizen, and Cheng, 2009) (0.96–0.99).

Figure 5. Scatterplot presenting the linear relationship between the HALO[®] and inclinometer for internal rotation in prone and supine.

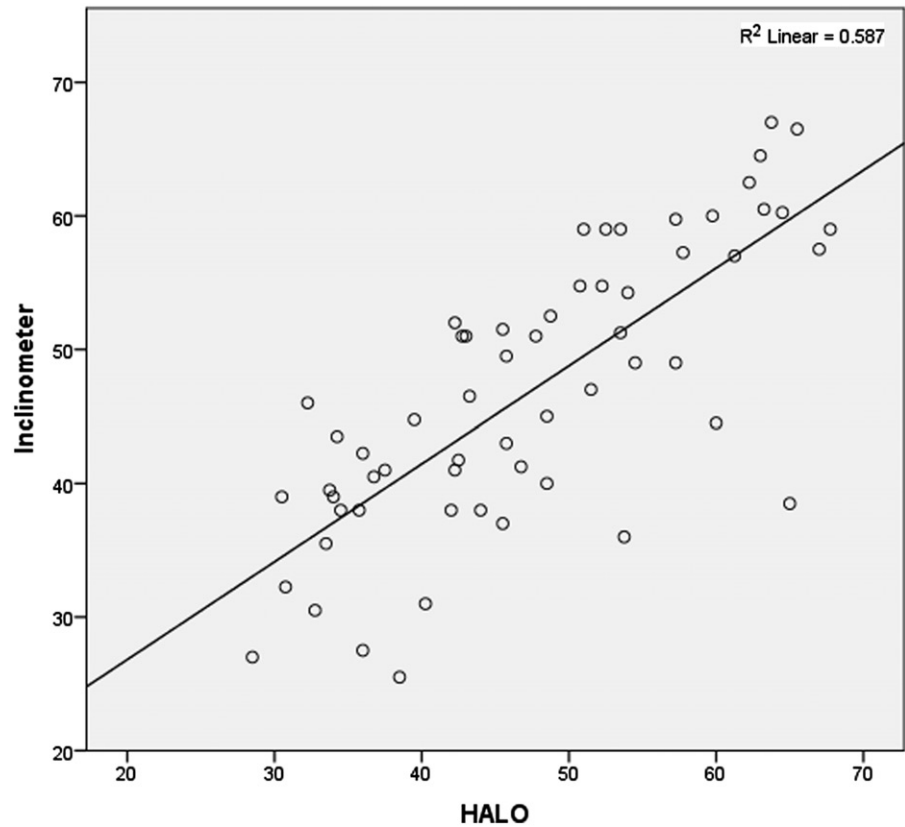
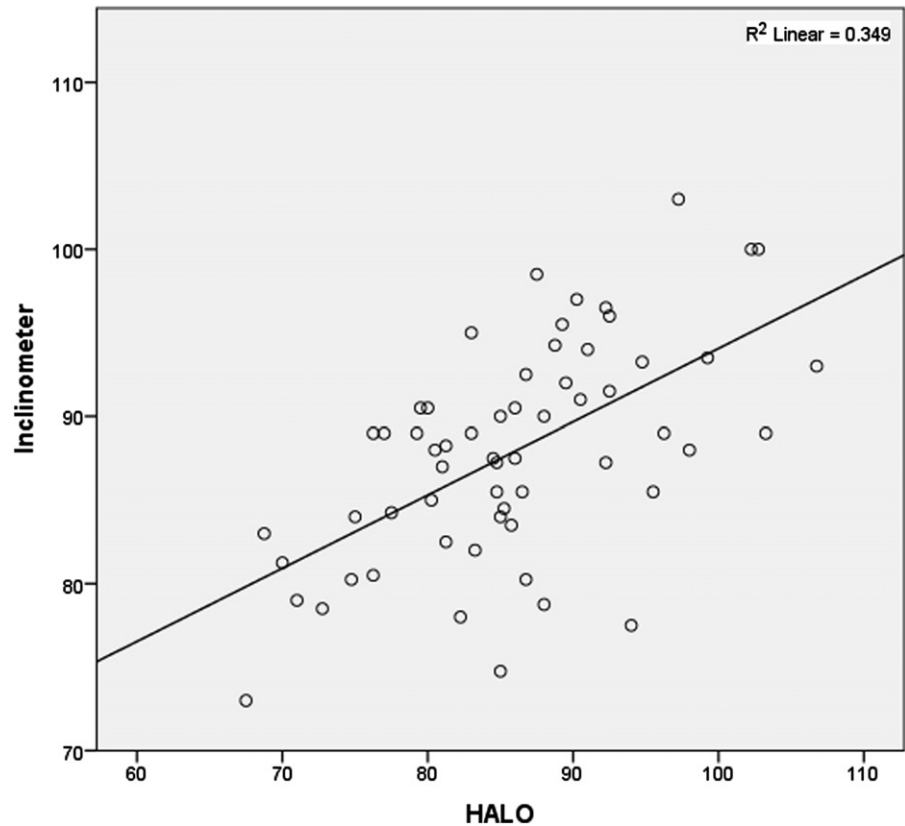


Figure 6. Scatterplot presenting the linear relationship between the HALO[®] and inclinometer for external rotation in prone and supine.



A thorough literature search revealed no published research investigating the reliability and/or validity of the HALO[®] device. The current results indicated excellent within session (ICC = 0.97–0.99) and between session reliability (ICC = 0.84–0.96) for the HALO device[®]. As this is a portable device

(~\$259.00 US currency), the new information offers clinicians an alternative assessment tool in measuring active shoulder internal and external rotation in prone or supine. It must also be noted that higher SEM and SRD values were associated with the HALO[®] when compared with the inclinometer (Tables 2 and 3). This was

predominantly seen in supine when considering IR (inclinometer SRD = 7.5, HALO© SRD = 16.1). This may be attributed to difficulty in maintaining the HALO© against the lateral forearm while also palpating for any humeral head movement with the free hand. When performing this measurement with the inclinometer, the device is easier to hold in one hand and maintain the position on the distal forearm. This is seen through higher ICC values and lower SEM and SRD values for the movement and position.

The secondary aim of this study was to determine whether discrepancies exist in shoulder ER and IR ROM in a prone versus supine position. Results revealed a significant difference in ER in prone versus supine when using either device. IR showed no significant differences between prone and supine. These findings show a distinct trend for the assessment of shoulder ER regardless of device.

The hypothesized reasons for the greater ER in prone compared to supine in this current study may be attributed to the reduced scapula compression in the prone position. Previous research has illustrated a reduction in shoulder ROM the more the scapula is stabilized and/or compressed (Lunden, Muffenbier, Giveans, and Cieminski, 2010). When in supine, the scapula is indirectly compressed and stabilized through direct pressure from the plinth surface. Although scapula position is controlled for in the prone position through a standardized testing protocol, there is no direct pressure from the plinth to compress and add stability to the scapula. Secondly it could be speculated that an increased muscular effort in prone may occur as the participant attempts to overcome this anti-gravity position. In prone, there may be greater co-contraction of the peri-scapula muscles (rhomboids, mid/lower traps) in conjunction with the external rotators (teres minor, infraspinatus). This may lead to greater muscular recruitment and therefore greater range of motion.

The premise for this study was to design a sport specific screening method for the shoulder. These results have indicated the need to assess ER in a consistent position. Bearing this in mind these results would indicate a surfer should be assessed in a prone position. Additionally a clinician may choose to utilize the prone position to assess/screen functional stability and structural restriction around the shoulder; especially considering that ER is assisted by gravity in the supine position. One could assume that a ROM greater than the normative values attained from uninjured surfers could clear the joint for functional stability and of any structural restriction. A reduction of ER in the prone position could indicate further testing around the shoulder is needed. It is imperative that normative values are attained from uninjured surfers to determine the appropriate ROM to clear the shoulder. It also needs to be noted that other prone dominant sports such as swimming could utilize this prone position to assess shoulder ER.

Results for IR ROM (46.6°) are similar to previous published research which has specifically looked at prone IR (Kolber, Saltzman, Beekhuizen, and Cheng, 2009) 43° and 55° respectively. Unfortunately, both studies did not assess ER in prone therefore comparisons for this movement cannot be made.

The third aim was to determine the validity of the HALO© device. Inclinometers are widely used and accepted in clinical practice and therefore were the benchmark to determine the concurrent validity for the HALO© device. Figures 5 and 6 represent the linear relationship between the two devices. A significant correlation was identified through ICC test (IR = 0.87, ER = 0.72) assuring the HALO© and inclinometer are measuring the same movement.

There are several limitations that exist in this current study. First, it was difficult truly blinding the tester when using the HALO© device. This was due to the large digital display and having to wait 2–3 s for the device to settle. As inter-rater reliability was not assessed, this needs to be recognized when

applying these results to clinical practice especially when more than one clinician is treating the same patient. Finally, a standardized approach should be adopted to ensure reproducible effort by the patient between sessions, however this is extremely difficult to control.

Conclusion

This research has identified that greater ER is achieved in prone compared to supine regardless of device. Bearing this in mind, clinicians need to be aware of this when performing initial and follow-up assessments and determining change. These findings also stress the need for established norms in the prone position and in a surfing or swimming population where ROM may exceed non-prone dominant athletes. Prone assessment was also a reliable position to assess shoulder range of motion. It would seem more logical to adopt this sport specific position when working with prone dominant athletes (surfing or swimming). Finally, as a significant correlation exists between the HALO© and inclinometer; this supports the use of either device in clinical practice as a reliable and valid tool.

Declaration of interest

None of the authors benefited directly or indirectly from this study.

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Appendix

Details of testing positions and device placement.

Prone testing: start position

Participants were positioned on in a prone position with the arm being assessed over the edge of the plinth. The arm was then taken into 90° of abduction, the forearm flexed to 90° and the wrist placed in neutral pronation/supination (Clarkson, 2005). The angle of abduction was confirmed through goniometric measurement. A rolled towel was placed under the upper arm so that the humerus was visually level with the acromion process. This ensured a neutral horizontal positioning of the arm.

Device	Movement	Procedure
HALO©	Internal rotation	The HALO© was placed on the mid-point of the lateral forearm. The mid-point was determined as half way between the ulnar styloid and the olecranon. Subjects were instructed to actively rotate the arm as far as possible. The device remained in this position until end of range where a reading was taken. The examiner's free hand was lightly placed over the lateral epicondyle to limit any horizontal extension of the shoulder or extension of the elbow.
	External rotation	The HALO© was placed on the mid-point of the lateral forearm. Subjects were instructed to externally rotate the arm. From this prone position, examiners were able to visually see any thoracic extension or scapula retraction and correct this with verbal cueing.
Inclinometer	Internal rotation	Subjects were instructed to internally rotate the arm. As per the HALO©, light pressure was placed over the lateral epicondyle ensuring pure rotation. At the end of range, the inclinometer was placed on the anterior forearm adjacent to the radial styloid and the measurement taken.
	External rotation	Subjects were instructed to externally rotate the arm. The inclinometer was placed as per internal rotation and the measurement recorded. Examiners visually monitored for any thoracic extension or scapula retraction.

Supine testing: start position

Participants were positioned in a supine position with the olecranon at the edge of the plinth. All other aspects of the starting position were the same as the prone set-up.

HALO©	Internal rotation	The HALO© was placed on the mid-point of the lateral forearm. The examiner's other hand palpated the anterior humeral head and coracoid process. Active rotation was performed and subjects instructed to stop when scapula movement was felt.
	External rotation	The HALO© was placed on the mid-point of the lateral forearm. Subjects were instructed to externally rotate and the HALO© remained on the forearm until end of range where the measurement was taken.
Inclinometer	Internal rotation	The inclinometer was placed on the anterior forearm adjacent to the radial styloid. The movement was palpated as mentioned in HALO© internal rotation.
	External rotation	Subjects were instructed to externally rotate the arm. At the end of range, the inclinometer was placed on the anterior forearm adjacent to the radial styloid and the measurement taken.
