A new method of measuring shoulder hand behind back movement: Reliability, values in symptomatic and asymptomatic people, effect of hand dominance, and side-to-side variability

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ABSTRACT

Shoulder Hand behind back (HBB) range of motion (ROM) is a useful measure of impairment and treatment outcome. The purpose of this repeated measures study was to identify inter- and intra-rater reliability, of a new simplified method of measuring HBB ROM. Two experienced raters measured HBB ROM with a bubble inclinometer on 25 people (aged 42-75 years, 14 female) with unilateral shoulder dysfunction and 25 age and gender matched asymptomatic subjects on two different occasions. Statistical analysis included calculation of Intra-class correlation coefficients (ICC), minimal detectable change (MDC), standard error of measurement (SEM), Pearson correlation coefficient (r), coefficient of determination (R^2) and the lower bound score. Mean HBB ROM was 108.6° (SD 16.30) and 23.9° (SD 10.46) on the pain-free and symptomatic side respectively. Both intra - rater and inter - rater reliability was high (ICC > 0.80). For asymptomatic people the SEM was at most three degrees and MDC was eight degrees with a strong correlation between the dominant and non-dominant side (r > 0.72). The mean absolute values and lower bound scores were at most 10.2˚ and 26.0˚ respectively. These results indicate that this new and novel method of measuring HBB ROM is accurate, has good inter-and intra-rater reliability, and provides normal values for between limb ROM variability.

Key words: Hand behind back, shoulder, reliability

INTRODUCTION

Shoulder region complaints are ranked third after the spine and knee as the most common musculoskeletal disorders (Sharma, 2012). Impairments in shoulder range of motion (ROM) and pain may negatively impact on activities of daily living as well as occupational and recreational activities. Such impairments include inability to reach the hand either overhead or behind the back (Magee, 2006). These impairments pose functional limitations for example when dressing or when self-grooming (Kisner and Colby, 2007). In this respect, in addition to examination of cardinal plane ROM (Reese and Bandy, 2002), examination of functional movements are a highly appropriate measure of impairment and indirectly of disability (O'Sullivan and Sdmlllz, 2007) and should be used as an integral part of the physical examination and to measure treatment progress.

Hand behind back (HBB) movement is considered an important objective functional measure, which is the combination of shoulder internal rotation/adduction, extension and elbow flexion (Mallon, et al, 1996; Wakabayashi, et al, 2006). Various attempts have been made to provide valid and reliable means of measuring this movement. Previous reports of the measurement of HBB ROM rely on visual estimation (Hayes, Walton, Szomor, Murrell, 2001), highest anatomical landmarks reached (Green, Buchbinder, Forbes, Bellamy, 1998; Hoving et al, 2002), or use of a tape measure by measuring the distance between the tip of the thumb or radial styloid process and vertebral spinous processes (Edwards et al, 2002; Ginn, Cohan, Herbert, 2005; Han et al, 2012). These methods have been shown to have poor reliability due to difficulties with the identification of bony landmarks (Christens et al, 2002; Seffinger et al, 2004; Stochkendahl et al, 2006; Haneline and Young, 2009; Robinson, Robinson, Bjorke, Kvale, 2009) or due to obesity (McKenzie and Taylor, 1997). Moreover, the tape measure method cannot be used in patients with severe limitations of movement (Han et al, 2012). The method proposed by van den Dolder, Ferreira, Refshauge (2013) involves measurement of the distance between the tip of the thumb and midpoint of two posterior superior iliac spines (PSIS). This method has been shown in asymptomatic people to have excellent intra-rater (ICC = 0.95) and inter-rater (ICC = 0.96) reliability with a minimal detectable change (MDC) of 12.8 mm and standard error of measurement (SEM) of 4.3 mm. (van den Dolder, Ferreira, Refshauge, 2013).

Although less expensive, all the methods proposed require patient's skin exposure for marking of landmarks which may not be permissible in multicultural countries. To overcome this issue, Sraj (2015) proposed to measure HBB by determining the angle in degrees between the line of the ulnar and the vertical plane (Sraj, 2015). However this method requires the use of a modified standard goniometer with custom made pendulum. To simplify this measurement, we developed the use of a bubble inclinometer to measure elbow flexion as a proxy for HBB ROM. The reliability of this measurement method has not been previously reported. Furthermore, normal side-to-side variation in ROM has not been established for this test. Clinicians commonly use the difference in ROM between limbs in an individual patient to determine when movement impairment is detected. Hence, it is important to know a cut-off point for when movement impairment is probable. The purpose of this study was to determine inter- and intra-rater reliability, accuracy, mean values and between-limb variability in HBB ROM in asymptomatic people and people with shoulder dysfunction. Our hypotheses were that reliability and accuracy would be high for this novel method of measurement for shoulder HBB ROM along with low levels of between limb variability in ROM.

METHODS

This repeated measures study investigated inter- and intra-rater reliability, mean values, and effect of between-limb differences of a new novel method of measuring HBB ROM in 25 symptomatic and 25 age and gender matched asymptomatic people.

Subjects

Subjects in the symptomatic group were recruited from the outpatient department of Smt. Kashibai Navale Medical College and General Hospital, Narhe, Pune, India. Subjects were included in this group if they were aged 18-70 years, with a history of acute or chronic shoulder pain and movement impairment identified by an orthopaedic surgeon. A total 53 subjects presented with various shoulder pathologies and were assessed by an orthopaedic surgeon. Of these, 23 were excluded due to lack of movement impairment. 30 subjects with shoulder pain and movement impairment were evaluated with five excluded based on the following extended exclusion criteria: a history of glenohumeral dislocation or subluxation and past history of shoulder complex surgery or recent shoulder fractures. Thus a total 25 symptomatic subjects were enrolled in this study (Figure 1).

Insert Figure 1 about here

The asymptomatic group comprised a sample of convenience of age and gender matched subjects without shoulder pain and disability, recruited from the same medical institution.

Sample size estimate was calculated with respect to intra- and inter-rater reliability for two examiners and two repeated trials, with an estimated ICC value of 0.70 and 95% confidence interval of 0.20. Based on this estimate, the required sample size was determined to be 25 subjects in each group (de Vet, Terwee, Mokkink, Knol, 2013).

Raters and Instruments

Two experienced raters (one and two); physiotherapists with a minimum of 12 years clinical experience and five years of undergraduate teaching experience independently measured HBB ROM using a bubble inclinometer (Baseline, USA). This device consisted of a fluid-filled chamber covered with movable 360-degree scale divided into1-degree increments.

Procedure

An independent person allocated consecutive subjects to each rater in random order using a computer generated randomisation process to prevent order effects. Subject’s demographic data including age, weight, and height and side-dominance were recorded. In the symptomatic group, duration of symptoms, average pain intensity determined by a visual analogue scale (VAS) (Hawker, Mian, Kendzerska, French, 2011) and functional capacity determined by the Shoulder Pain and Disability Index (SPADI) (Roach, Budiman-Mak, Songsiridej, Lertratanakul, 1991) were recorded.

Following this, the procedure was explained to the subject and a demonstration was given to familiarise the subject with the required movement. While in a standing position, subjects were instructed to actively move their hand behind their back, as high as possible keeping the dorsum of their hand in contact with the posterior aspect of the trunk while avoiding shoulder elevation or any spinal movements. Inappropriate movement was monitored and corrected by the rater before final measurements were taken. Subjects were directed to reach their thumb to the highest point possible in the midline along the line of the spinous processes. Once reaching the end-position the arm was supported and stabilized by rater while measurements were taken from the bubble inclinometer applied at lateral aspect of radius proximal to radial styloid process. For all subjects, the maximum HBB ROM was considered when either pain limited the movement or the person was unable to move further even with encouragement. Zero degrees of elbow flexion would indicate a complete lack of HBB movement, while greater range of elbow flexion represented increased HBB ROM. All measurement sessions were carried out at approximately the same time of day and the average of three readings were taken and recorded in degrees. (Figure 2)

Insert Figure 2 about here

After completing the measurements and following a five-minute rest period, the second rater who was blind to the first measurements repeated the same measurement procedure to determine inter-rater reliability. To determine intra-rater reliability the same procedure was repeated by one rater two days later utilizing the same examination process. This rater did not have access to previous data recording sheet ensuring blinding.

Written informed consent was obtained from subjects who volunteered to participate in this study. Approval was granted by the ethical committee of Smt. Kashibai Navale College of Physiotherapy Narhe, Pune, India.

Data analysis

The Statistical Package for Social Sciences (SPSS 19) software was used for statistical analysis. Descriptive statistics were calculated. Inter-rater and intra-rater reliability was established by calculating Intra-class correlation coefficients (ICCs) with 95% confidence intervals (CIs) (Shrout and Fleiss, 1979) using a two-way ANOVA mixed model for absolute agreement of single measures. The cut off values for acceptable reliability at 95% confidence were ICC > 0.80 indicating high reliability; ICC > 0.60 to ≤ 0.80 moderate reliability; ICC > 0.40 to ≤ 0.60 fair reliability; and ICC ≤.0.40 poor reliability (Fleiss, Levin, Paik, 2003). The SEM and the MDC at 95% CI (MDC_{95}) was calculated and expressed in degrees.

Two-tailed paired t-tests were performed to determine the difference between dominant and non-dominant limbs in asymptomatic subjects for each examiner. Relationship in ROM between limbs was calculated using the Pearson correlation coefficient and coefficient of determination (R^2). Since mean difference between limbs does not account for negative values, the mean absolute values (MAV) were calculated to determine differences between sides while adjusting for negative scores (Covill and Petersen, 2011). A lower-bound score, upper limit of a tolerance interval for a one-sided t-test, was used to determine the cut-off point at which the degree of difference between sides could be considered greater than that accounted for by measurement error and variability. This calculation identified an upper threshold for which 95% of the left to right limb ROM differences can be expected in a similarly age matched population with 95% certainty (NIST/SEMATECH, 2012). Mean difference scores and 95% CI were calculated for the difference in ROM on the symptomatic side and the equivalent side in the asymptomatic group.

RESULTS

A total of 50 subjects were included in this study. Of these, 25 had shoulder pain and movement impairment (14 females and 11 males, mean age 56.8 years SD 8.18) and 25 were age and gender matched asymptomatic subjects. Descriptive statistics for the symptomatic and asymptomatic subjects are presented in Table 1. In the symptomatic group, the side of dysfunction was the right in 15 subjects and left in ten subjects. The right arm was dominant in 21/25 of the asymptomatic group and 21/25 in the symptomatic group.

Insert Table 1 about here

The minimum and maximum value for HBB ROM measured in the symptomatic group was nine degrees and 47° respectively. Table 2 provides the summary of Intra-rater and Inter-rater reliability analysis, the ICCs and associated 95% CIs, SEMs, and MDC at the 95% confidence level values of HBB ROM for both groups. Both intra-rater and inter-rater reliability was high when tested in symptomatic and asymptomatic people (Table 2), with ICC values greater than 0.80 (Fleiss, Levin, Paik, 2003)

Insert Table 2 about here

A two-tailed paired t-test identified a significant difference in HBB ROM between sides in the symptomatic group for rater one (p=0.008) and rater two (p=0.013). Mean ranges and mean differences between dominant and non-dominant sides with SD, 95% CI, Pearson correlation coefficient, and coefficient of determination for HBB ROM in asymptomatic people are shown in Table 3.

Insert Table 3 about here

The MAV and lower bound scores shown in Table 4 reveal relatively small variability between the dominant and non-dominant limb in asymptomatic people for either rater. These data indicate that we can be 95% sure that 95% of similarly aged people would have between side differences in HBB ROM of no greater than 26˚.

Insert Table 4 about here

An independent t-test identified a significant difference in HBB ROM between the symptomatic arm and the matched side in the asymptomatic group ($p<0.001$). Range was found to be 108.6˚ (SD 16.30) in asymptomatic people and 24.6˚ (SD 10.10) on the side of dysfunction in people with shoulder pain and movement impairment. Mean ranges and mean difference scores between the symptomatic arm and matched arm in the asymptomatic group with SD and 95% CI, are shown in Table 5.

Insert Table 5 about here

DISCUSSION

The present study has demonstrated that a new novel method of measuring shoulder HBB ROM via elbow flexion is both accurate and reliable when measured with a bubble inclinometer. In this measurement method, elbow flexion serves as a proxy for HBB ROM where by HBB ROM is expressed in degrees. The observed difference in range between asymptomatic people and the symptomatic side in people with shoulder pain and movement impairment indicates a substantial and clinically meaningful difference (Table 5).

Reliability for repeated measures found in the present study is similar to some previous investigations for measurement of HBB ROM (van den Dolder, Ferreira, Refshauge, 2013; Sraj, 2015). For example in asymptomatic people, excellent reliability (ICCs> 0.95) was reported for HBB ROM measured in degrees (Sraj, 2015) and measured by a tape measure (van den Dolder, Ferreira, Refshauge, 2013).

Reliability of the measurement in symptomatic people is better than reported for other measures of shoulder movement (Triffitt, Wildin, Hajioff, 1999, Winter et al, 2004). Triffitt, Wildin, Hajioff (1999) found greater variability in inclinometric measurements of shoulder movements, however the measuring instrument was not well defined.

In the present study, a bubble inclinometer was placed on the lateral border of the radius, proximal to the radial styloid process, which can be easily located potentially improving reliability (Lumley, 2008). In addition, reliability may have been improved by passively stabilizing the arm at the end of active HBB ROM, to allow for accurate measurement. Furthermore, the tape measure method may not be appropriate for use in patients with severe deficit of HBB movement where the minimum requirement is to reach the hand at least to the sacral spine. In contrast, the measurement method used in the present study enables clinician's to asses even markedly restricted HBB movement, where the elbow is unable to flex more than a few degrees taking the hand up the back.

The error in measuring ROM is represented by the SEM and the MDC. The MDC provides an estimate of the difference in ROM required to identify a clinically meaningful change after an intervention (Fletcher and Bandy, 2008). The largest SEM value across the symptomatic and asymptomatic groups was at most three degrees. The values for MDC indicate that to detect a real change in HBB ROM requires a difference of at least eight degrees in asymptomatic people and five degrees in patients with shoulder dysfunction. This is the first study to report HBB ROM in degrees using this new novel measurement method in a patient population presenting with shoulder pain and movement impairment. Mean range of HBB on the symptomatic side of people with shoulder pain was, much less than the contralateral side which was more consistent with the normal values in asymptomatic people (Table 5). The difference in range between impaired side and matched side of symtomatic controls was substantial, which is much greater than the MDC score as shown in Table 2.

In the past, shoulder HBB ROM has been assessed using a variety of different measurement methods including gravity dependent goniometers (Sraj, 2015) and a tape measure (Edwards et al, 2002; Ginn, Cohan, Herbert, 2005; Han et al, 2012; van den Dolder, Ferreira, Refshauge, 2013). This new method of measurement for the functional movement of HBB has an advantage over the tape measure method as it does not require a bony landmark as a reference point and does not require the exposure of the back. Hence this method may be preferable, as disrobing a patient might not be possible for cultural reasons.

A comparison of values for HBB ROM on the dominant and non-dominant side (Table 3) with previous studies is difficult as the same measurement method has not been previously utilized. The closest study reported mean HBB ROM of 95° (95%CI 55° to 131˚), similar to the present study, however no differentiation for hand dominance was made in that report (Sraj, 2015). The present study's finding of reduced HBB ROM for the dominant shoulder is supported by previous reports indicating significantly less internal and more external rotation ROM on the dominant side in a range of athletic (Ellenbecker et al, 2002; Baltaci 2001, 2004; Meister et al, 2005) and non-athletic populations (Conte, Marques, Casarotto, Amado-Joao, 2009; Vairo, Duffey, Owens, Cameron, 2012). Hence it is important for the clinician to be aware of the effect of hand dominance when assessing potential shoulder ROM impairment.

A number of explanations may be hypothesized for the significant reduction in HBB ROM on the dominant compared to non-dominant side in asymptomatic people (Table 3). These include the effects of repeated movements on the dominant shoulder. Repeated external rotation during functional activities of daily living on the dominant side (Conte, Marques, Casarotto, Amado-Joao, 2009) may cause stretching of capsular, ligamentous, and myofascial structures, potentially leading to adaptive tightness of the posterior capsule (Tyler, Roy, Nicholas, Glein, 1999). It has been proposed that posterior capsular tightness causes the humeral head to migrate anteriorly, which may not allow the normal translation of the humeral head within the glenoid (Lin, Lim, Yang, et al, 2006). Side-to-side differences in the starting position of humeral head may then act as an early mechanical block to internal rotation movement, in turn causing HBB ROM deficit. Another explanation may be due to changes in muscle tone around the shoulder associated with different patterns of muscle activation on the dominant and non-dominant side (Wang, Macfarlane, Cochrane, 2000; Baltaci, 2001). Alternatively, side-to-side differences in humeral retroversion (such as seen in athletes with repetitive overhead arm activity) may cause reduced range of internal rotation and hence differences in HBB ROM (Crockett et al, 2002).

Despite the current study's findings of differences in ROM between sides in asymptomatic people, the data indicates a significant relationship between the limbs for HBB ROM. We found a strong correlation in HBB ROM between the dominant and non-dominant side ($r > 0.72$) in asymptomatic people. Furthermore, the MAV's for intra-individual difference in ROM between the sides indicate relatively small variability between the dominant and non-dominant limbs (Table 4). Thus it would seem reasonable to deduce that range of one side can be used to predict range of the opposite side which may have clinical significance when trying to identify movement impairment. The potential difference in ROM between the dominant and non-dominant side is represented more accurately with the lower bound score (Table 4). The lower bound score suggests that for experienced raters variability greater than 26° can be judged to be greater than normal side-to-side variability between the dominant and non-dominant limb.

It is important to recognise that our study did not attempt to investigate the construct validity of this new measurement method. Further studies are required to elucidate this. However, in support of this method, Mallon et al (1996) showed that shoulder HBB ROM is a composite of shoulder internal rotation, adduction, elbow flexion and various scapular movements (Mallon et al, 1996). During HBB movement, maximum internal rotation (mean 39.8°) occurs in the initial phase of movement, following which elbow flexion dominates once the hand crosses the lumbar spine (Wakabayashi et al, 2006). Hence, HBB should not be used as an alternative measure for glenohumeral joint internal rotation. Rather, HBB is an additional functional movement, important for activities such as dressing and toileting (Ginn, Cohen, Herbert, 2006) and has been shown to be an useful measure for identifying shoulder movement impairment and clinical effectiveness of interventions for shoulder disorders (Green, Buchbinder, Forbes, Bellamy, 1998).

One of the strengths of our study is that the population evaluated is from a typical Indian hospital orthopaedic outpatient clinic with typical levels of disability and duration of symptoms, similar to many patients seen in physiotherapy practice. Specific shoulder disorders were not a requirement for entry into this study and the symptomatic group probably had a wide variety of different shoulder pathologies presenting with shoulder pain with movement impairment. Finally, the bubble inclinometer measuring device is portable, light weight and relatively inexpensive, enabling broad use.

There are some potential limitations to our study's findings. The measurement procedure proposed may not be suitable for patients with limited elbow flexion and forearm pronation. In addition only experienced raters were used. Future studies should be repeated with multiple assessors with varying clinical experience and with a wide spectrum of subject ages, as the effect of age was not investigated in this study.

CONCLUSION

This study examined a novel method of measuring HBB ROM using a bubble inclinometer and found high intra- and inter-rater reliability in asymptomatic people as well as in a population of people with shoulder pain and movement impairment. The SEM is at most three degrees and MDC is eight degrees when measured by an experienced clinician. Variation greater than 26˚ between sides can be interpreted to be greater than normal side-to-side variability and may be of clinical significance.

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DECLARATION OF INTEREST

The authors report no declarations of interest

TABLES

Table 1: Subject characteristics

Characteristics	Symptomatic Group (n=25) MEAN (SD)	Asymptomatic Group (n=25) MEAN (SD)
Weight (kg.)	62.74 (7.62)	63.50 (8.29)
Height (cm.)	159.72 (7.58)	161.10 (9.11)
Symptom duration (Wks)	16.72 (9.14)	
Pain (VAS)	6.40 (1.46)	
SPADI	59.52 (9.65)	

SD standard deviation; kg kilograms; cm centimeters; Wks weeks; VAS visual analogue scale; SPADI – shoulder pain and disability index.

Table 2:

Summary of reliability analysis of hand behind back (HBB) range of motion (ROM) on the affected side in symptomatic participants and on the dominant and non dominant side in asymptomatic participants

	Intra-rater reliability				Inter-rater reliability			
HBB ROM	**ICC**	**95% CI for ICC**	**SEM In degrees**	**MDC_{95} In degrees**	**ICC**	**95% CI for ICC**	**SEM In degrees**	**MDC_{95} In degrees**
Affected side	0.97	0.95-0.99	1.53	4.24	0.96	0.91-0.98	2.00	5.54
Dominant Side	0.98	0.97-0.99	1.97	5.46	0.97	0.93-0.98	2.94	8.14
Non Dominant Side	0.97	0.93-0.98	2.64	7.31	0.97	0.93-0.98	2.79	7.73

Abbreviations: HBB hand behind back; ROM range of motion; ICC intra class correlation coefficient; CI confidence interval; SEM standard error of the measurement; MDC_{95}, minimal detectable change at the 95% confidence level;

Table 3

Rater one and two determined mean ranges, mean differences between dominant and non-dominant sides (SD) with 95% confidence interval (CI), Pearson correlation coefficient (r), and coefficient of determination (R^2) for hand behind back range of motion (HBB ROM) in asymptomatic participants (n=25)

Measurement	**HBB mean ROM° (SD)**		**Mean difference scores (95% CI)˚**	**r**	R^2
	Dominant	**Non-dominant**			
Rater one	100.4 (18.13)	107.7 (15.62)	7.24 (2.03, 12.45)	0.76 p=0.008	0.57
Rater two	102.0. (17.00)	108.7 (16.30)	6.68 (1.56, 11.80)	0.72 p=0.013	0.52

Table 4

Mean absolute differences (MAV) in hand behind back (HBB) range of motion (ROM) between the dominant and non-dominant sides together with lower-bound scores in asymptomatic participants (n=25)

Rater	**MAV (SD)˚**	**Lower-bound scores˚**
Rater one	10.01 (8.37)	23.8
Rater two	10.20 (9.60)	26.0

Table 5

Rater one and two determined mean ranges (SD) and mean differences between the symptomatic arm and matched arm in the asymptomatic group with 95% confidence interval (CI) for hand behind back range of motion (HBB ROM)

Rater	Mean HBB ROM° (SD)		Mean difference scores (95% CI)°
	Symptomatic arm	Asymptomatic group	
1	23.9 (10.46)	108.6 (16.30)	-84.76 (-92.55, -76.97)
2	24.6 (10.10)	102.0 (17.00)	-77.40 (-85.35, -69.45)

Figure Captions

Figure 1: Flow chart of the participants through the study.

Figure 2: Hand Behind Back measurement as measured with a Bubble Inclinometer.