Title: The effect of load on biomechanics during an overhead lift in the WorkHab Functional Capacity Evaluation

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Abstract

Objective: The role of biomechanics during the overhead lift has not been widely investigated. This study aimed to evaluate any change in biomechanics between safe minimum and safe maximum overhead lifts during the WorkHab Functional Capacity Evaluation.

Method: Thirty healthy participants (age range 18-22 years) were videotaped completing the overhead lift. Images at the beginning (0/3), one-third (1/3), two-thirds (2/3), and end of lift (3/3) were collected for the minimum and safe maximum lifts. Measurement of joint angles of the wrist, elbow, shoulder and sagittal spine using Dartfish Pro-suite software was completed. Paired t-tests were used to analyse the differences in joint angles between lifts.

Results: Participants' biomechanics changed between the minimum and maximum lifts. In comparison to minimum lifts, there was increased wrist ulnar deviation (10.50, 95% CI 4.39, 16.61, p=0.002), increased shoulder flexion (7.26, 95% CI 0.50, 14.01, p=0.036), increased thoracic extension (-3.40, 95% CI -5.36, -1.45, p=0.001), increased lumbar extension (3.75, 95% CI 1.39, 6.12, p=0.003), and decreased elbow flexion (-11.28, 95% CI -18.57, -4.00, p=0.004) in the maximum lifts.

Conclusions: The results of this study provide insight into biomechanical changes during the overhead lifting, and support the clinical judgements made by the WorkHab assessor in determining safe maximal lift.

Key Words: lifting, functional capacity evaluation, work capacity evaluation biomechanics.

1. Introduction

Manual handling injuries are a major burden on the working population, health system and social societies worldwide [1, 2]. Injuries from manual handling both in and outside the workplace continue to have a significant impact on society. These include physical and psychological disability, which impacts upon an individual's quality of life and result in lost productivity, both in the workplace and the home[3, 4]. In the 2007/08 period, 8,875 workplace manual handling injuries were reported in NSW, Australia with an estimated cost of AUD $164 million [5]. In the United Kingdom manual handling injuries make up a third of all major work injuries reported each year [6]. In 2007, 24% of the total burden of workplace injuries were due to overexertion (manual handling tasks) at a cost of $12.7 billion in the US [7].

Manual handling is defined as any activity requiring force by a person to lift, lower, push, pull, carry or otherwise move, hold or restrain any animate or inanimate object [8]. Lifting makes up a significant proportion of manual handling in workplaces and society in general.

There is evidence that lifting overhead carries an increased risk of musculoskeletal injuries [9, 10]. Lifting overhead can be defined as any lift above shoulder height. Overhead is defined as where hands reach a point just above the head height and above the line of vision [11]. The risk of shoulder injury increases when the hands reach shoulder level and therefore may increase further with lifting overhead [12, 13]. It has been found that workers in the construction industry spend an estimated 31%-36% of their working day with their arms overhead [14]. Much research discusses the floor to bench lift, however numerous studies have indicated a need for further research on overhead lifting to investigate the biomechanics, loads placed on the body and limitations of this lift [15-18].

Safe lifting guidelines have been developed in an attempt to prevent or reduce injuries. Most guidelines tend to be task based (such as the Australian National Standard for Manual Tasks [8], NIOSH lifting equation [19], and the WorkCover NSW Manual Handling Risk guide [20]), or based on physiologic measures such as perceived exertion and heart rate rather than the biomechanics of lifting [21]. The guidelines advise against overhead lifting, due to the risk of musculoskeletal injury. Biomechanics play a significant role in lifting; it has been shown that altered biomechanics during lifting tasks can cause increased joint stress and an increased risk of injury [15, 22]. A biomechanical analysis of lifting offers insight into the changes which occur to the body in terms of mechanical load on joints [23], and can be used to estimate the forces which are being placed on specific joints during lifting. Guidelines that recommend avoiding overhead lifting are supported by evidence of potentially harmful altered biomechanics or increased injury risk [15-18]. Spinal extension has been shown to increase compressive forces through the spine and increase the risk of injury [15, 16, 24]. The shoulder flexion required for overhead work is a risk factor for shoulder pain, particularly rotator cuff injuries [9, 10, 25]. Furthermore the weight of the object, the distance from the body and shape of the object being lifted can further influence the stress placed on the body [24, 26]. Since increased shoulder flexion and lumbar spine extension are necessary to successfully lift an object overhead, the biomechanical demands of the overhead lift could contribute to the increased risk of injury when lifting.

Functional Capacity Evaluations (FCE) are a common assessment tool used in work injury prevention and occupational rehabilitation [17, 27, 28] and are used to objectively measure a person's functional ability to perform work tasks safely and productively [17, 29]. FCE's are often used following a work related injury to determine a person’s ability to meet required job demands. FCEs are also used to assist in cost-effective rehabilitation helping develop return to work guidelines and rehabilitation programs to determine work readiness and also aid in medico-legal issues [30-34]. They are typically constructed of a series of tests looking at the persons mobility, strength, cardiovascular fitness, tolerance to postures and movements, and manual handling abilities [35].

There are many types of FCEs available [17]. Studies have found that clinicians use commercially available FCEs but also modify these to suit individual clients [29, 36]. The use of FCEs is widespread across Australia with the WorkHab FCE identified as the most commonly used commercially available assessment in NSW [29, 33, 36]. Research studies that investigate aspects of reliability and validity of a selection of commercially obtainable FCEs have been published and several authors have reviewed this literature, however there is limited research on the psychometric properties of the WorkHab FCE [17, 34, 37-40]. Test re-test reliability of the manual handling component of the WorkHab FCE with healthy adults was investigated with results showing substantial levels of test-retest reliability with this group. The manual handling scoring scale, as part of the WorkHab FCE was also investigated and had good internal consistency [41]. In another study, substantial levels of intra-rater agreement and inter-rater reliability were identified for the manual handling scoring system, and safe maximal lift determination during the floor to bench, bench to bench and bench to shoulder lifts of the WorkHab FCE [42]. There remains a lack of literature in relation to the overhead lift as part of this FCE.

This study used the repetitive lifting component of the WorkHab FCE in order to investigate the biomechanics of the overhead lift. The hypothesis is that there are biomechanical differences between lifting a light load overhead compared to lifting a safe maximal load overhead as determined by the WorkHab FCE. The purpose of this study is to show that the clinical judgement of the therapist, in determining the safe maximal lift, is supported by evidence of biomechanical change. It will also provide insight into the biomechanics of overhead lifting.

2. Method

2.1 Subjects

Participants were recruited via email from the School of Health Sciences at the University, and posters placed around the University campus. Any student or staff member with no reported musculoskeletal injuries was invited to participate. Participants were excluded if they had medical conditions which would preclude them from completing manual handling tasks. Each participant gave informed consent and ethical approval was obtained from the Human Research Ethics Committee at the University. Thirty participants met the inclusion criteria : ten males and twenty females with a mean age of 20.9 years (SD 0.97, range 18-22).

2.2 Experimental design

The repetitive lifting component of the WorkHab FCE was simulated for this experimental study. A pre-screening assessment was performed on each participant prior to performing the lifting. This included a general health questionnaire, blood pressure measurement and a three minute step test to determine heart rate recovery. Participants' joints were then marked. A single researcher trained in physiotherapy joint palpation skills marked each participant to minimise variation. The wrist, elbow, shoulder, hip, knee and ankle were palpated to find the joint axis of movement. The joint axis for the wrist, elbow, shoulder, hip, knee and ankle was marked with a cross using indelible ink. The spinous processes of C7, T7, L3 and S2 were then palpated. The middle of each spinous process was marked with a cross; a foam ball was placed at the centre of the cross using double sided tape. The lifting protocol, including discussion on appropriate lifting technique, was explained to participants and they were instructed to lift with weight being increased after each 3 lifts. The heart rate monitor was used during the lifting to ensure participants did not reach their maximal heart rate. Participants were informed they could cease the lifting at any stage.

2.3 Measurement

Participants were video-taped using two Sony Handycam Camcorders (Model HRD-HC9E, Sony, Tokyo, Japan). The camera images were recorded digitally using Dartfish Pro-Suite (Dartfish, Lausanne, Switzerland). The cameras were set up to view the rear coronal and right sagittal planes during lifting. The manual handling component of the WorkHab FCE uses a modular box system. Boxes are set at an appropriate height relative to the individual. For the overhead lift the height for each participant was where the hands reached a point just above head height and above the line of vision at the end of the lift. Subjects were instructed to lift the load box, which has cut-out handles on the side (initially empty) from beginning to end height and return. This is repeated three times before additional weight is added to the load box. The FCE assessment follows a protocol of increasing load at each height until the safe maximum lifting limit is reached [11]. All participants began with the same minimum load of 0.85kg lifting from bench to overhead and weight was increased as per the WorkHab FCE protocol, until the participant reached their safe maximal lift as determined by the WorkHab assessor. The three indications listed in the FCE guidelines for ceasing lifting tasks are, the observation of compensatory or unsafe movements, participants reaching their maximum heart rate, or participants choosing to stop lifting.

2.4 Video Analysis

For each participant the video of the minimum and maximum bench to overhead lift was used for analysis. The second repetition of the lifts was used to create still images at four points during the lift. The lowest vertical displacement of the box prior to lifting was identified and marked with a horizontal line. The video was then played until the inferior edge of the box reached the highest vertical displacement of the lift. This was marked with a horizontal line. The 1.1m height WorkHab box was used as the reference height for each analysis. The distance between the lowest and highest vertical displacement was measured and divided into thirds. Each third was marked with a horizontal line and a still image of the lift saved at these points. This provided snapshots of the lift at the lowest (0/3), one-third (1/3), two-thirds (2/3) and highest (3/3) vertical displacement of the lift (Fig 1). The images were de-identified and randomised prior to biomechanical analysis.

2.5 Data Analysis

Biomechanical analysis was performed using Dartfish Pro-suite software which allows calculation of angles using on screen drawing tools. Joint angles were measured as described in Table 1. For reliability, measurements were independently repeated for five subjects selected at random. Intra-rater and inter-rater reliability were determined from these measurements using intraclass correlation coefficients (ICC's) and are reported in Table 2.

Descriptive statistics were used to analyse data. Means and 95% confidence intervals (CI) were used to analyse the joint angles at each point in the minimum and maximum lifts and paired t-tests to compare the mean joint angles for minimum and maximum lifts at each point of the lift. All statistical analyses were performed using JMP 8.0 (SAS, Cary, USA).

3. Results

The sample consisted of thirty participants: ten males and twenty females with a mean age of 20.9 years (SD 0.97, range 18-22).

The average maximum weight lifted for females was 7.46kg (SD 1.36, range 5.0-11.0). The average maximum weight lifted for males was 11.20 kg (SD 2.97, range 8.0-19.4).

To determine reliability of measurements, intra-rater and inter-rater reliability of five randomly selected subjects were completed .Two researchers, independently analysed the video data as per the instructions outlined in Table 1. The results are presented in Table 2. The lower limb and lateral flexion of the spine measurements were not reliable. This may be due to some of these movements occurring in the oblique range which was not captured in the video footage in this study. As such only the upper limb and sagittal spine movements, which are considered the most relevant for the overhead lift, are further reported.

The mean joint angles for each point in the minimum and maximum lift for all participants are shown in Table 3. The main findings were a significant difference in wrist and spinal angles between the minimum and maximum lift .It can be seen there were increases in joint angles in the wrist (ulnar deviation) and in shoulder flexion between the minimum and maximum lift at all four points of the lift. This ranged from 8.98º to 18.86º in the minimum lift to 15.81º-29.37º in the maximum lift in the wrist. There was a decrease in elbow flexion between the minimum and maximum lift at all points of the lift. There was a decrease in thoracic extension at all points in the lift (25.53º to 17.27º in the minimum lift and 24.2º to 13.87º in the maximum lift) and in lumbar extension the mean joint angle between the minimum and maximum lift increased at the 1/3rd, 2/3rd and 3/3rd positions of the lift (31.49º to 29.95º at 1/3rd and 28.71º to 33.7º at the end of the lift). The mean difference in joint angles between minimum and maximum lifts at each of the four points is shown in Table 4.In the maximum lift participants were in more ulnar deviation (p=0.002) and spinal extension: thoracic extension (p=0.001), and lumbar extension (p=0.003) than in the minimum lift (Table 4).The elbow was in more extension and the shoulder in more flexion in points of the maximum lift compared to the same points of the minimum lift (Table 4).

4. Discussion

This experimental study investigated the biomechanics of the overhead lift during the WorkHab FCE with a group of young healthy adults. The results demonstrated there are biomechanical differences occurring in the upper limb and spine when lifting a minimum load compared with lifting a maximum load from bench to overhead height. The height of the overhead lift was relative to each individual, as per the WorkHab FCE protocol. In the maximum lift the wrist was in more ulnar deviation and the spine in more extension, suggesting increased forces being placed through these joints

[15, 43]. The increase in extension of the elbow and flexion of the shoulder in the maximum lift, despite the height of the lift remaining unchanged, suggests that it could be compensatory due to increased extension of the spine.

Biomechanical Changes

At the wrist, ulnar deviation was significantly greater throughout the maximum lift with the greatest difference between the minimum and maximum lift, of 10.50 degrees, at the end of the lift (Table 4). Normal range of ulnar deviation has been found to be 30.0 - 37.2 degrees [44, 45]. The mean ulnar deviation in the maximum lift peaked at 36.16 degrees at the 2/3 point of the lift, which indicates participants were approaching the end limits of range (Table 3). This suggests large increases in radiolunate and ulnocarpal stresses in the wrist during the maximum lift which can increase the risk of wrist injuries [43].

Ulnar deviation involves complex motion of the carpal bones and has been implicated in the development of carpal tunnel syndrome, a common and debilitating injury in the working population [46, 47]. Weiss et al. (1995) found ulnar deviation increases pressure in the carpal tunnel, which can result in either direct compression of the nerve or vascular insufficiency of the median nerve [48, 49]. Carpal tunnel syndrome is one of the most common peripheral neuropathies and has an estimated incidence of 3.8% in the general population [50-53]. The incidence of carpal tunnel syndrome has been shown to be higher in some industrial populations in Canada [54]. In the US the medical expenses from work-related carpal tunnel syndrome costs $US13,263 per employee affected [55]. Excessive and repetitive ulnar deviation has also been linked with other conditions such as de Quervains tenosynovitis and lateral epicondylitis [56, 57]. Ulnar deviation approaching the end of range of movement has been found to have a higher perceived rate of discomfort during reaching tasks therefore lifting with ulnar deviations in these ranges could result in significant discomfort [58].

Studies have found that the handle position on objects being lifted affects the biomechanics of the wrist [59, 60]. The findings of this research could contribute to determining handle positions in which excessive forces and postures of the wrist are minimised. Implementation of these in the workplace may lead to strategies to decrease musculoskeletal injuries of the wrist during overhead lifting.

Biomechanical changes also occurred at the elbow. It was in greater extension in all parts of the maximum lift compared with the minimum lift except at the end of the lift (point 3/3). This contradicts a number of safe lifting guidelines in which it is recommended to keep the load as close to the body as possible. Elbow extension may increase the distance of the load from the body. However, the increase in elbow extension in this study may be related to the increase in shoulder flexion in the maximum lift. The shoulder was in increased flexion in the maximum lift (0/3 point, 1/3 point and 3/3 point) when compared with the minimum lift (Table 4). Considering the height of the lift remained unchanged between minimum and maximum lifts (relative to each individual's height), the elbow would need to extend more as the shoulder flexes in order to place the box at the same height. These two biomechanical differences may have arisen to compensate for the increase in extension of the spine, which also occurred in the maximum lift.

Participants demonstrated increased thoracic extension during the maximum lift compared to the minimum lift (Table 4). Participants also had significantly greater lumbar extension in the last two thirds of the maximum lift compared to the minimum lift (Table 4). Safe lifting guidelines recommend maintaining neutral curves in the lumbar and thoracic spine during lifting to minimise the risk of injury. Extension not only causes increased compressive forces but also increases the shear forces through the spine [15]. These forces have been shown to contribute to intravertebral disc injuries, particularly those of the annulus fibrosis [61]. Active muscle force in the back extensors is increased in this situation, which has also been shown to increase spinal compression [62, 63]. Excessive lumbar extension or repetitive extension loads the inferior articular facets of the spine and can cause injury to the pars interarticularis [61].

Biomechanical compensations in the spine have been linked to an increase risk of injury. [9, 15, 62]. This is clinically relevant as low back pain has been identified as the most frequently reported symptom among manual handling workers, with one of every two likely to report a lower back disorder in a twelve month period [64]. Back injuries also represented 24% of all major workplace injuries in 2007-2008 in NSW, Australia (Workcover NSW). The maximum average weight lifted by male (11.20kg) and female (7.46kg) participants in this study, compares with less than 25% of the industrial population being able to perform this lift overhead as found by Snook in his research findings [21, 65].

Variation in Lifting Styles

Differences in overhead lifting styles were also observed in this study. The two main styles observed were 1) participants stepped forward and positioned both feet close to the overhead lift and 2) participants stepped only one leg forward closer to the overhead lift. Within these two styles there were variations in the timing of lifting, with some beginning as they stepped forward and others after they had stepped forward. The two lifting styles differ mainly in lower limb position, and could be observed separately to explore any biomechanical differences between minimum and maximum lifts within each style. Timing and pacing are aspects that are considered as part of the manual handling score of the WorkHab FCE and used in conjunction with other aspects of the principles of safe manual handling in the determination of a safe maximal lift [11].

Application in Clinical Practice

Safe maximal lifting (SML) limits have been proposed according to lifting height, frequency and worker characteristics [21] and the compression force on the spine [66]. The principles of safe manual handling techniques are used to determine SML: a steady base of support; neutral spinal curves; loads kept close to the spine and within range of gravity where possible; no twisting; and movements that are smooth and controlled [11]. Observation of the recruitment of upper extremity strength for the ability to control the lift and the ability to stabilise the lumbo-sacral spine without hyperextension is suggested for the overhead lift during the WorkHab FCE[11]. Other observations recommended for determination of safe maximal lift include, muscle bulging of prime movers, involuntary use of accessory muscles, altered body mechanics including counterbalancing, loss of equilibrium, increased base of support, decreased efficiency and smoothness of movement, cardiovascular signs (heart rate and breathing patterns) and referred symptoms [67]. Determination of the safe maximal lift by the WorkHab assessor is based on objective physiological measures, observation of biomechanics, and participant's report of pain and exertion. With respect to observation of biomechanics, the assessor is mainly concerned at looking for compensatory techniques to assist in determining safe maximal lift. In line with the recommendations for SML determination, WorkHab FCE assessors are trained to look for compensations with respect to stance: the ideal placement of the feet and a stable base; posture: maintenance of normal lordosis throughout the lift; leverage: keep loads close to the body and in the range of centre of gravity; torque: no rotation of the shoulder relative to the pelvis, and pacing: the use of smooth and controlled movement patterns The changes in stance, posture and leverage that the assessor was observing to determine safe maximal load are supported by the biomechanical changes identified in the upper limb, thoracic and lumbar spine, between the minimum and maximum lift in this study. This study therefore provides evidence to support the use of these biomechanical observations as part of the determination of safe maximal lift during the WorkHab FCE. Further research is needed to investigate what specifically defines safe maximal lift when considering the postures and joint angles identified in this study and to investigate other clinical reasoning processes used by health professionals to determine SML .

4.1 Limitations

The young average age (20.9 years) of participants in this study may not be representative of the working population who are required to lift overhead.

There were also limitations with some of the measurements. Some participants were observed to perform movements in the oblique plane which was not able to be measured in this study due to the position of the video cameras. This occurred in the lower limb with external rotation of the hip and affected measuring ankle dorsiflexion in the sagittal plane. The reliability of the markers used for measuring hip flexion could also have been improved using the S2 or L3 marker on the spine instead of C7, allowing a more accurate measurement of true hip flexion.

4.2 Implications for future research

Further research based on the biomechanics of the overhead lift is needed to investigate which changes are significant with regards to risk of injury. Further studies would enable development of safe lifting guidelines for the overhead lift. Implementation of such guidelines in the workplace has the potential to help decrease the risk of musculoskeletal injuries. In addition, future studies can use the biomechanical changes particularly in ulnar deviation of the wrist to further investigate the role of handle placement and its links to musculoskeletal injuries with manual handling.

Grouping participants into lifting styles prior to biomechanical analysis may enable statistically significant differences in the biomechanics of the lower limb to be detected. A comparison between the two lifting styles would allow any biomechanical advantages or disadvantages of either style to be detected. The use of two lateral views may enable analyses of any biomechanical differences between participant's dominant and non dominant sides. This could be particularly relevant when looking at the different lifting styles observed in this study.

5. Conclusion

This study showed that biomechanical differences occur in the wrist, elbow, shoulder and sagittal spine when lifting a light load compared to a safe maximal load overhead, as defined by the WorkHab FCE[11]. The potential increased risk of injury which may accompany the increases in joint stress supports the use of FCE's in the workplace to determine lifting abilities with significant biomechanical differences being identified by the WorkHab assessor, as part of their clinical reasoning processes. Further investigation into the clinical reasoning used in determining a safe maximal lift is recommended.

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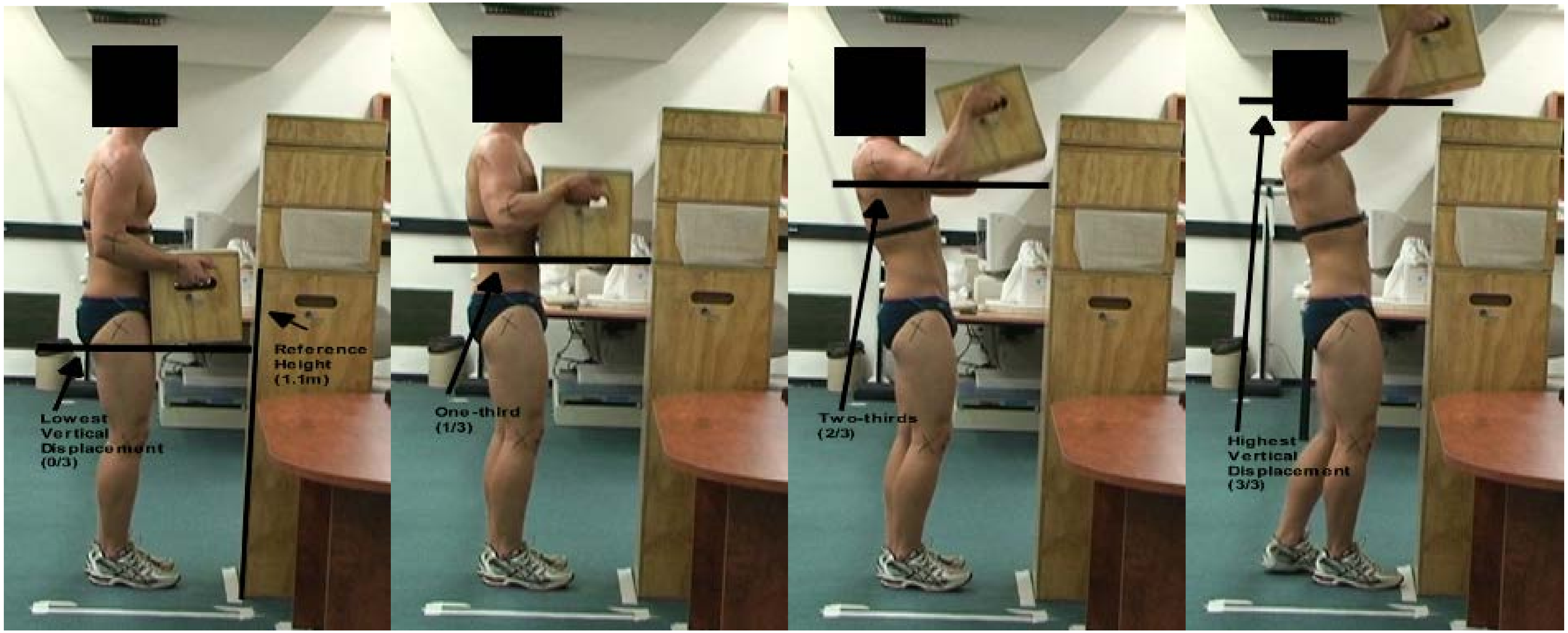

Figure 1.

The four points in a participant's maximum lift: 0/3, 1/3, 2/3, 3/3.

Table 1

Summary of methods use to measure joint angles.

Joint	Joint Axis	Landmarks used to measure angle	Angle measured
Ulnar deviation	Base of the third metacarpal	Head of the third metacarpal, base of the third metacarpal, elbow joint axis	Acute angle
Elbow Flexion	Lateral epicondyle of the humerus	Base of the third metacarpal, lateral epicondyle of the humerus, lateral aspect of the centre of the humeral head	Acute angle
Shoulder flexion	Lateral aspect of the centre of the humeral head	Lateral epicondyle of the humerus, lateral aspect of the centre of the humeral head, greater trochanter of the femur	acute angle positive result is flexion negative result is extension
Shoulder Abduction	midpoint of the posterior aspect glenohumeral joint	Olecronon of ulna, midpoint of the posterior aspect of the glenohumeral joint, parallel to the spine	Acute angle
Hip flexion	Greater trochanter of the femur	C7 foam ball, greater trochanter of the femur, lateral epicondyle of the femur	acute angle positive result is flexion negative result is extension
Knee Flexion	Lateral epicondyle of the femur	Greater trochanter of the femur, lateral epicondyle of the femur, inferior to the lateral malleolus of the tibia	acute angle
Plantar flexion	Inferior to the lateral malleolus of the tibia	lateral epicondyle of the femur, lateral malleolus of the tibia, parallel to the sole of the heel	acute angle positive result is dorsi-flexion negative result is plantar-flexion
Thoracic extension	T7	Centre of the foam ball at C7, T7, L3	180 degrees-acute angle A decrease in the angle is in the direction of extension
Lumbar extension	L3	Centre of the foam ball at T7, L3, S2	180 degrees –acute angle A decrease in the angle is in the direction of flexion
Thoracic lateral flexion	T7	Centre of the foam ball at C7, T7, L3	180 degrees- acute angle
Lumbar lateral flexion	L3	Centre of the foam ball at T7, L3, S2	180 degrees-acute angle

Table 2

Reliability of joint angle measurements.

	Intra-Rater Reliability		Inter-Rater Reliability	
Joint	ICC	95% CI	ICC	95% CI
Ulnar deviation	0.92	0.85, 0.96	0.82	0.68, 0.90
Elbow flexion	0.99	0.99, 1.00	0.97	0.81, 0.99
Shoulder flexion	0.99	0.98, 1.00	0.99	0.98, 1.00
Hip flexion	0.26	-0.27, 0.33	-0.04	-0.25, 0.21
Knee flexion	0.95	0.88, 0.97	0.94	0.89, 0.97
Plantar flexion	0.81	0.57, 0.91	0.57	0.32, 0.75
Thoracic extension	0.83	0.70, 0.91	0.74	0.56, 0.86
Lumbar extension	0.91	0.83, 0.95	0.81	0.66, 0.89
Thoracic Lateral Flexion	0.39	0.10, 0.62	0.08	-2.34, 0.38
Lumbar Lateral Flexion	0.021	-0.29, 0.33	-0.01	-0.30, 0.30

Table 3

Mean joint angles at each point of the minimum and maximum lifts.

Joint	Point of lift[a]	Minimum Mean	Minimum 95% CI	Maximum Mean	Maximum 95% CI
Ulnar deviation	**0/3**	8.98	4.45, 13.50	15.81	10.29, 21.32
	1/3	15.30	9.40, 21.19	25.36	19.18, 31.54
	2/3	25.85	20.47, 31.23	34.86	28.76, 40.96
	3/3	18.86	14.65, 23.08	29.37	23.89, 34.85
Elbow flexion	**0/3**	92.80	85.14, 100.48	86.29	80.16, 92.41
	1/3	100.87	96.20, 105.53	93.75	88.58, 98.91
	2/3	79.91	73.57, 86.26	68.63	61.41, 75.86
	3/3	24.78	21.30, 28.26	19.99	14.07, 25.91
Shoulder Flexion	**0/3**	-7.27[b]	-11.26, -3.28	-1.83	-6.22, 2.55
	1/3	16.93	10.62, 23.24	24.19	18.74, 29.63
	2/3	65.16	58.88, 71.45	70.26	63.59, 76.92
	3/3	113.24	109.96, 116.53	116.59	112.26, 120.93
Thoracic extension[c]	**0/3**	25.53	22.75, 28.30	24.2	21.80, 26.60
	1/3	24.29	22.44, 26.14	22.81	20.71, 24.91
	2/3	19.68	17.86, 21.50	18.18	16.09, 20.28
	3/3	17.27	15.35, 19.19	13.87	11.53, 16.21
Lumbar extension[d]	**0/3**	25.09	21.74, 28.45	25.75	22.29, 29.22
	1/3	31.49	25.74, 37.24	28.71	25.03, 32.40
	2/3	29.93	25.80, 34.06	33.34	29.50, 37.18
	3/3	29.95	26.52, 33.39	33.7	29.65, 37.77

a. 0/3, 1/3, 2/3, 3/3 are the beginning, one-thirds two-thirds and end point of the lift respectively

b. A negative shoulder angle indicates the joint is in extension

c. A decrease in thoracic angle is in the direction of extension

d. An increase in lumbar angle is in the direction extension

Table 4
Mean differences between minimum and maximum lift at each point of the lift

Joint	Point of Lift	Mean	95% CI	P value
Ulnar deviation	0/3	6.83	1.20, 12.47	0.019
	1/3	10.06	2.49, 17.64	0.011
	2/3	9.01	1.57, 16.45	0.019
	3/3	10.50	4.39, 16.61	0.002
Elbow flexion	0/3	-6.52	-12.07, -0.97	0.023
	1/3	-7.12	-11.90, -2.34	0.005
	2/3	-11.28	-18.57, -4.00	0.004
	3/3	-4.793	-10.84, 1.26	0.116
Shoulder flexion	0/3	5.44	1.58, 9.29	0.007
	1/3	7.26	0.50, 14.01	0.036
	2/3	5.09	0.36, 10.55	0.066
	3/3	3.35	0.20, 6.50	0.038
Thoracic extension[b]	0/3	-1.33	3.79, -1.14	0.280
	1/3	-1.48	-2.95, 0.00	0.050
	2/3	-1.50	3.46, 0.46	0.129
	3/3	-3.40	-5.36, -1.45	0.001
Lumbar extension[c]	0/3	0.66	-2.65, 3.97	0.686
	1/3	-2.78	-10.26, 4.71	0.454
	2/3	3.41	0.42, 6.40	0.027
	3/3	3.75	1.39, 6.12	0.003

a. 0/3, 1/3, 2/3, 3/3 are the beginning, one-thirds two-thirds and end point of the lift respectively

b. A decrease in thoracic angle is in the direction of extension

c. An increase in lumbar angle is in the direction extension