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Original article

Overhead shoulder press – In-front of the head or behind the head?

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Abstract

Background: Using a cross-sectional design comparison was made of two overhead press techniques (in-front of the head or behind the head). The purpose of this study was to determine the impact of behind the head or in-front of the head overhead pressing technique on shoulder range of movement (ROM) and spine posture. The overhead press is commonly prescribed exercise. The two techniques (in-front of the head or behind the head) may influence joint mechanics and therefore require an objective analysis.

Methods: Passive shoulder ROM quantified using goniometric measures, dynamic ROM utilised three dimensional (3D) biomechanical measures (120 Hz) of 33 participants performing overhead pressing in a seated position. The timing and synchronisation of the upper limb shoulder and spine segments were quantified and influence of each technique investigated.

Results: The in-front technique commenced in lordotic position, whilst behind the head technique commenced in kyphotic position. Behind the head technique started with less thoracic extension than in-front condition. The thoracic spine remained extended and moved between 12° and 15° regardless of gender or technique. The techniques resulted in a significant difference between genders. Males were able to maintain a flat or normal lumbar lordosis, whereas females tended to kyphotic.

Conclusion: Shoulder ROM was within passive ROM for all measures except external rotation for males with the behind the head technique. To avoid possible injury passive ROM should be increased prior to behind the head protocol. Females showed greater spine movements, suggesting trunk strengthening may assist overhead pressing techniques. For participants with normal trunk stability and ideal shoulder ROM, overhead pressing is a safe exercise (for the shoulder and spine) when performed either in-front or behind the head.

Q1 *Keywords:* 3RM; (4–6) – Spine flexion, head; ROM; Shoulder flexibility; Shoulder press

1. Introduction

Overhead barbell press exercises are regularly prescribed in athletic, recreational, and rehabilitative environments as a means to strengthen the shoulder girdle musculature. The human shoulder is not well designed for overhead activity due to the lower cranial orientation of the glenoid fossa and a smaller supraspinatus muscle when compared with primates.[1,2] Alterations to normal head and shoulder girdle posture from injury, or habit, cause forward and dropped shoulders. Anatomically this can impact on both the orientation of the glenoid fossa and the function of the scapulothoracic stabilisers.[3] This musculoskeletal-realignment can result in muscle imbalance and subsequent shoulder injuries.[4–6] Exercises to strengthen the shoulder girdle commonly include a range of overhead pressing movements. Despite being a frequently prescribed exercise the technique protocol (in-front of the head or behind the head) of the overhead press is not commonly provided or possible differences quantified.[7–9] Consequently the limited biomechanical understanding between the possible technique protocols has evolved into a contentious matter.[10]

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As with other exercises the overhead press activity can be performed with a number of variations including seated or standing, narrow or wide-hand width of grip, and the use of bars or dumbbells.[11−13] Common across all of these variations is the pressing technique of in-front or behind the head. The overhead pressing technique has been described with limited detail for behind the head barbell pressing,[10,14] standing overhead pressing,[13] and dumbbell press[11] yet is rarely (never) monitored or controlled in research publications. Seated overhead pressing is more common in the clinical setting due to supposed reduced impact on the spine posture, although there is no evidence of this found in the literature.

One of the common issues associated with shoulder injury is a loss of normal range of movement (ROM) for rotation; both internal and external; of the shoulder. Normal shoulder ROM has been reported from a range of studies along with contrary findings of a 40°−43° reduction in internal ROM, but with normal external ROM.[15−18] Body builders have also been reported as having a reduced range of internal rotation ROM 60° and normal ROM for external rotation of 107°.[19] Kolber and colleagues[20] suggest the position assumed for a behind the head press is unfavourable as it takes the shoulder into a simultaneous abducted and externally rotated "high-five" position, yet the specific angle of external rotation required for this movement has not been reported. The literature suggests that participants in both overhead sports and strength training may incur reductions in internal rotation ROM with no real difference in external rotation ROM.[5,17,20] Further, passive ROM for shoulder flexion, abduction, and horizontal adduction appear to differ very little between overhead athletes and the normal population. Studies comparing active versus passive ROM suggest active ROM is generally 5°−10° degrees less than the passive ROM.[21] Active and passive ROM for the overhead press was not found in the literature.

Whilst the focus of previous research has been on the shoulder it is also important to consider the effect of overhead pressing on the adjacent anatomical region, the spine. The orientation, and subsequent movement of the spine, will naturally influence the action of the adjacent shoulder orientation, and therefore these two regions should be analysed simultaneously. No reported literature was found to describe influence and changes in spine posture during overhead pressing. The literature does suggest that in the seated position, overhead pressing may invoke greater core stability muscle, but no measures of change in spine posture were included in this study.[8] Finally there are no studies providing evidence of any gender differences in the performance of overhead pressing movements. Gender differences have been reported in some lower body exercises such as squatting,[17,22] but it is not known if differences exist for overhead press.

Therefore, the aim of this research was to determine the impact of behind or in-front of the head overhead pressing technique on shoulder ROM and spine posture. To address this aim the timing and synchronisation of the upper limb shoulder and spine segments were quantified, with respect to the different technique protocol. To enable individual-specific prescription guidelines to be further established, parameters of segment lengths and gender were also quantified.

2. Materials and methods

From a cross-sectional group of 33 participants (18 males and 15 females), anthropometric measures were taken. Passive ROM was quantified using standardised goniometric measures (Table 1). Three dimensional (3D) dynamic ROM of the shoulder and spine was determined during the overhead seated press. Informed consent was obtained and all participants informed of the experimental risks according to guidelines of the University Human Research and Ethics Committee. Ethics Approval number: A/10/226. All subjects had at least 12 months overhead pressing experience and were free of musculoskeletal injury.

Participants attended two sessions of testing which involved anthropometric, passive ROM, and three repetition maximum (3RM) strength exercises during the first session with 3D motion data collection second. Anthropometric data collected for each subject included total body mass to the nearest 0.1 kg, and standing height, arm span, elbow span, bi-acromial width measured to the nearest 0.001 m. Passive ROM of the shoulder girdle collected using a goniometer included flexion, abduction, internal rotation, external rotation, and horizontal adduction. Goniometric measures were as per standardised methods in a supine position.[23] Shoulder flexion was measured relative to the frontal plane, with 180° being shoulder flexion above the head relative to the midline of the thorax. Similarly shoulder abduction was measured relative to the sagittal plane, with 180° being shoulder abduction above the head. Shoulder rotation was measured in supine position with start position of shoulder 90° abducted and elbow 90° flexed referenced as 0°. The shoulder was externally rotated to assess length of the internal rotators, so that the forearm was in the frontal plane palm face up, the value would be 90°. Shoulder horizontal adduction was measured relative to the frontal plane, with arm adducted to 90° and in frontal plane being 0°. If the arm was taken

Table 1
Subject data, anthropometric measures, passive joint ROM, and 3RM (mean ± SD).

Measure	Male	Female
Age (year)*	28.6 ± 4.8	25.0 ± 4.1
Weight (kg)*	86.3 ± 10.3	64.3 ± 4.4
Height (m)*	1.823 ± 0.087	1.670 ± 0.048
Arm span (m)*	1.844 ± 0.079	1.652 ± 0.048
Elbow span (m)*	1.087 ± 0.081	0.911 ± 0.052
Bi-acromial width (m)*	0.397 ± 0.023	0.357 ± 0.012
Shoulder flexion (degrees)*	158.8 ± 6.3	167.9 ± 8.3
Shoulder horizontal adduction (degree)*	−28.1 ± 12.6	−33.5 ± 4.7
Shoulder abduction (degrees)*	163.7 ± 13.0	169.9 ± 7.0
External shoulder rotation (degrees)*	84.7 ± 12.4	89.3 ± 12.4
Internal shoulder rotation (degrees)	44.5 ± 15.8	46.9 ± 11.0
In-front 3RM (kg)*	50.7 ± 4.9	28.0 ± 4.4
Behind head 3RM (kg)*	49.8 ± 5.2	27.4 ± 4.2

*Initial measures differed significantly between genders ($p < 0.01$).
Abbreviation: 3RM = three repetition maximum.

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behind the frontal pane measures were then recorded as a negative value. Overhead press was performed in a seated position on a standard free weight bench with no back support using an Olympic bar (Australian Barbell Company, Mordialloc, Victoria, Australia) and associated weights. Floor height was adjusted to ensure the participants' hips and knee angles were always at 90° at commencement of the movement.

Strength testing followed protocols previously recommended.[24] Subjects completed their normal warm-up which included some general movement of the whole body followed by preliminary warm-up sets for each exercise. Testing for the initial protocol commenced with the first set being six repetitions at estimated 60% of 3RM, followed by five repetitions at 70%, four repetitions at 80%, three repetitions at 90%, and then three repetitions in increasing increments until failure. If a comfortable 3RM attempt was successful, further weight was added until 3RM was reached. Subjects were allowed 5-min rest between efforts. Order of protocol for in-front and behind the head was randomised and a 20-min rest was allowed between protocols. Second protocol commenced with three repetitions at 90%, and then three repetitions in increasing increments until failure. Certified strength coaches supported technique and safety spotting, when required, and participants were encouraged during their 3RM testing. Width of grip was measured to be half-way between bi-acromial width and elbow span widths and repeated for both in-front and behind the head techniques. Bar height during descent was standardised at a height equal to C7 on each participant. No significant difference ($p \geq 0.05$) existed between participants' right and left sides across all measured variables, therefore only the left side data were used.

Data of the upper limbs and torso was captured (Fig. 1) for one set of three repetitions in-front of the head and repeated for behind the head technique. The type order was randomised to account for order effect and there was 5-min rest between data collection sets. Data were collected by 3D Motion Analysis System (Motion Monitor, Version 6.50.0.1 Innovative Sports Training, Chicago, IL, USA) measured at 120 Hz. Sensors attached at the head, C7/T1, T12/L1, L5/S1, angulus acromialis (most laterodorsal aspect of the scapula), antero-medial aspect of the humeral shaft and antero-medial aspect of the distal ulna according to standardized Joint Coordinate System.[25] From these sensors common landmarks on the skeletal system was used to create a digitized virtual body. Further landmarks were then digitized using the sensors as reference for superior angle, inferior angle, and T8.

The independent variables were technique (in-front or behind) and gender (male or female). The dependent variables for active ROM data were: (1) shoulder flexion angle; (2) shoulder abduction angle; (3) shoulder rotation angle; (4) shoulder horizontal adduction angle; (5) cervical flexion angle (change in angle between the sensors on head and C7/T1); (6) cervical rotation angle; (7) thoracic flexion angle (change in angle between the sensors on C7/T1 and T12/L1); (8) lumbar flexion angle (change in angle between the sensors on T12/L1 and L5/S1); and (9) the normalized time (start of ascent being 0 and the top being 100%) of when these occurred. All angles are referenced to the global coordinates positioning reference with the participants facing the same direction as the "X" axis as is common practice in 3D motion analysis. Angle conventions for references are as follows. Shoulder flexion is from 0° to overhead full flexion 180°. Shoulder abduction is from 0° to overhead full abduction 180°. Shoulder external rotation for shoulder at 90° abduction and elbow at 90° flexion and forearm at 90° to frontal plane is 0°. Shoulder rotation occurs in external direction so that the forearm aligns with the frontal plane this would be recorded as 90°. Shoulder horizontal adduction behind the frontal plane that would be recorded as a negative number. Cervical flexion angle is reduced if the head moves forwards causing the spine to straighten and if the head tilts backwards increasing the cervical spine curve the angle is increased. Thoracic flexion angle increases positively when the thoracic spine slumps forwards and if the thoracic spine arches backwards and straightens past 0° it is now reported as a negative value. Lumbar flexion angle increases if the lumbar spine bends backwards and if movement occurs anteriorly and the lumbar spine straightens past 0° it is now reported as a negative value. Lordosis typically referred to the lumbar and cervical spine normal backward shape curvature and Kyphosis typically refers to the shape of the normal thoracic spine with a forward facing curvature.[26]

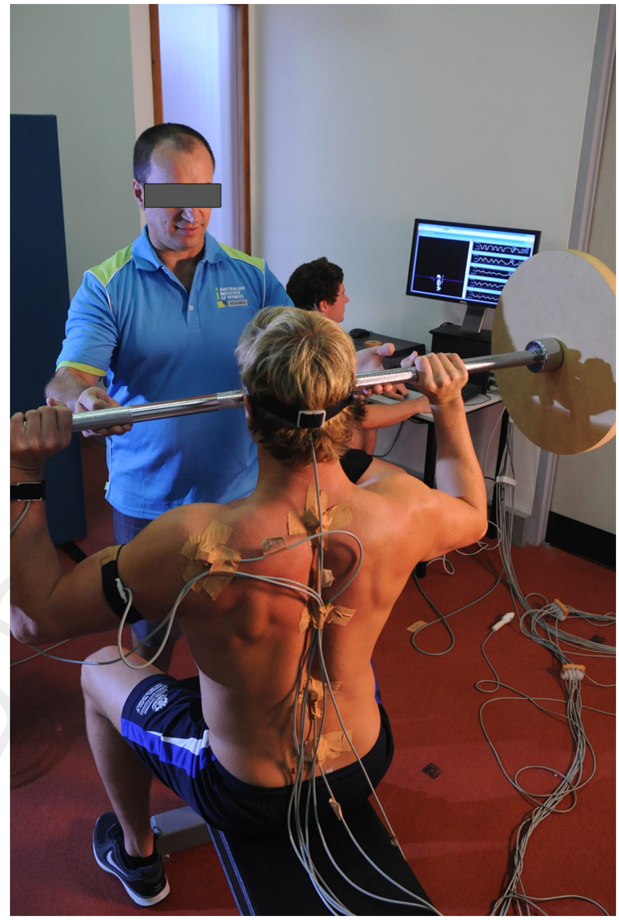

Fig. 1. Subject performing the in-front overhead press.

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Table 2
Cervical spine flexion and rotation presented as mean (95% CI) for gender and overhead press technique. A negative score indicates normal lordosis of the cervical spine. A positive score indicates loss of normal curve and anterior flexion of the cervical spine.

		Start position (degree)	Minimum (degree)	Minimum time (%)	Maximum (degree)	Maximum time (%)	Range (degree)
Cervical spine flexion							
Male	Behind^{i}	23.9 (17.9, 30.0)	11.9 (6.3, 17.4)	51.3 (64.9, 37.6)	54.4^{a} (41.6, 67.1)	24.9 (33.9, 15.8)	42.5^{b} (29.8, 55.2)
	Front^{i}	−8.5 (−12.2, −4.8)	−10.2 (−14.0, −6.3)	8.1 (13.9, 2.3)	8.5 (3.5, 13.6)	81.1 (91.2, 71.9)	18.7^{c} (15.4, 22.0)
Female	Behind^{j}	17.1 (12.2, 22.1)	13.8 (9.0, 18.5)	41.0 (56.7, 25.4)	30.6^{a} (24.5, 36.7)	33.9 (43.8, 24.1)	16.8^{b} (12.0, 21.7)
	Front^{j}	−8.4 (−13.1, −3.7)	−8.8 (−13.5, −4.1)	2.6 (4.9, 0.3)	15.6 (10.2, 21.1)	73.9 (81.5, 66.2)	24.4^{c} (20.4, 28.4)
Cervical spine rotation							
Male	Behind	19.6 (8.0, 31.1)	6.7 (−5.2, 18.6)	28.6 (40.2, 17.0)	31.4 (17.1, 45.7)	42.3^{f} (56.2, 18.4)	24.7 ^{dg} (19.3, 30.1)
	Front	15.2 (7.3, 23.1)	12.5 (4.6, 20.4)	36.2 (47.4, 25.0)	18.5 (10.7, 26.3)	74.0^{f} (84.3, 63.7)	6.0 ^{eg} (4.8, 7.2)
Female	Behind	11.4 (−2.9, 25.7)	3.5 (−11.5, 18.5)	25.4 (34.2, 16.5)	17.5 (4.0, 31.1)	45.3^{h} (59.0, 31.6)	14.0^{d} (10.1, 17.9)
	Front	14.1 (−0.6, 28.7)	11.5 (−3.4, 26.4)	28.9 (39.4, 18.5)	22.5 (8.8, 36.1)	74.0^{h} (75.4, 61.3)	11.0^{e} (7.4, 14.5)

$p < 0.05$, significant difference when comparing measures where same superscript symbol is used.

Each of these responses were analysed separately for differences between type (in-front or behind the head) and gender during the ascent phase of the movement. The cervical spine curvature has been previously classified as lordotic, using a negative value $< -4°$; kyphotic with a positive value $>4°$; and straight when within the range of $-4°-4°$.[27] The results were presented as mean and 95% CI. Bivariate Spearman correlations were then calculated between the different kinematic measures and the anthropometric measures for both gender and technique protocol. Correlations less than 0.4 represented poor correlations, 0.4−0.7 moderate, 0.70−0.90 good, and greater than 0.9 represented excellent correlations. Statistical interpretation focused on the main effects and the threshold for statistical significance was set to $p < 0.05$, using SPSS version 21.0 (IBM SPSS Inc., Chicago, IL, USA).

3. Results

Using combined gender data, height, and bi-acromial width achieved positive moderate correlations for 3RM scores ($r = 0.659-0.675$) and passive shoulder flexion ROM achieved negative moderate correlations ($r = -0.556$to-0.570) for 3RM scores. Arm span however achieved positive good correlations ($r = 0.734-0.754$) for 3RM scores. Height and arm span also had negative moderate correlations with lumbar flexion starting angles ($r = -0.458$to-0.492). Finally, thoracic start and minimum achieved a number of moderate to good positive correlations with lumbar flexion start and minimum and maximum angles ($r = 0.539-0.780$), whilst lumbar flexion maximum and thoracic flexion maximum angles achieved excellent positive correlations ($r = 0.926-0.965$).

Behind the head technique resulted in a starting position where cervical spine was placed in a forward flexed posture with total loss of cervical lordosis. In comparison the in-front technique maintained a lordosis in the cervical spine. The in-front of head technique resulted in small kyphosis of the cervical spine, whilst the behind the head resulted in quite a significant difference ($p < 0.01$) in kyphosis between genders, with males reaching 54.4° and females 30.6°. The behind the head technique minimum cervical curve occurred at about midway of the ascent (males 51.3%, females 41.0%). Whilst minimum cervical curve for in-front of head technique occurred towards the bottom, as the head was taken backwards from the bar. This increased normal lordosis of the cervical spine (males 8.1%, females 2.6%). This pattern was then reversed for the maximum cervical angle which occurred closer to the top for in-front of head (males 81.1%, females 73.9%), and nearer the bottom for behind the head (males 24.9%, females 33.9%). For all subjects the cervical spine achieved some form of rotation instead of remaining forward

Table 3
Thoracic and lumbar spine flexion presented as mean (95% CI) for gender and overhead press technique. A positive score for the thoracic spine indicates normal kyphosis and a negative score indicates loss of normal kyphosis and extension of the thoracic spine. A positive score indicates loss of normal curve and anterior flexion of the lumbar spine and a negative score indicates normal lumbar curve.

		Start position (degree)	Minimum (degree)	Minimum time (%)	Maximum (degree)	Maximum time (%)	Range (degree)
Thoracic spine flexion							
Male	Behind	−10.0^{a} (−16.1, −3.9)	−21.8 (−27.7, −15.9)	83.5* (90.7, 76.4)	−6.3^{b*} (−11.9,−0.7)	18.1 (40.7, 15.4)	15.5 (12.3, 18.7)
	Front	−15.25 (−20.0, −10.4)	−27.8 (−33.1, −22.5)	67.1* (77.7, 56.5)	−13.6* (−18.3,−8.8)	25.5 (40.5, 10.4)	14.2 (12.0, 16.4)
Female	Behind	−3.3^{a+} (−5.7, −0.9)	−16.4^{+} (−18.9, −13.9)	80.3^{+} (87.5, 73.1)	−1.9^{b+} (−4.0,0.3)	11.8 (17.8, 4.7)	14.6^{+} (12.65, 16.6)
	Front	−14.0^{+} (−16.4, −11.6)	−24.5^{+} (−27.4, −21.7)	61.5^{+} (71.1, 51.9)	−12.7^{+} (−14.5,−10.8)	23.5 (38.5, 8.5)	11.9^{+} (10.1, 13.7)
Lumbar spine flexion							
Male	Behind	−1.1^{c} (−6.3, 4.1)	−8.7^{d} (−14.5, −2.8)	62.6* (74.0, 51.1)	1.8^{e} (−3.6,7.2)	43.3^{f} (58.8, 27.7)	10.5 (8.9, 12.1)
	Front	−7.4^{g} (−12.4, −2.4)	−13.2^{h} (−18.3, −8.0)	44.8* (55.1, 34.6)	−3.2^{i} (−8.5,2.1)	46.8 (62.8, 30.7)	10.0 (8.4, 11.5)
Female	Behind	9.7^{c+} (6.0, 13.4)	2.8^{d+} (−1.5, 7.1)	71.6^{+} (82.2, 61.0)	11.2^{e} (7.4, 15.0)	23.1^{f+} (35.4, 10.8)	8.4 (6.8, 10.0)
	Front	3.2^{g+} (0.3, 6.1)	−3.1^{h+} (−6.7, 0.6)	51.5^{+} (60.1, 43.0)	6.3^{i} (2.3, 10.3)	51.0^{+} (67.8, 34.3)	9.4 (7.7, 11.1)

$p < 0.05$, significant difference when comparing measures where same superscript letter or symbol is used.
A superscript letter is used to compare gender and a superscript symbol is used to compare techniques with the same gender.

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Table 4
Shoulder flexion, abduction and rotation presented as mean (95% CI) for gender and overhead press technique.

		Start position (degree)	Maximum (degree)	Maximum time (%)	Range (degree)
Shoulder flexion					
Male	Behind	3.3^{a} (−4.6, 11.2)	144.7* (136.4, 153.0)	92.7 (97.7, 87.8)	141.4 (130.1, 152.8)
	Front	6.7 (0.8, 12.6)	135.9^{c} (129.7, 142.1)	98.6^{d} (99.3, 98.0)	129.1 (119.5, 138.8)
Female	Behind	22.2^{a} (9.3, 35.0)	155.0* (145.3, 164.7)	85.4 (92.5, 78.3)	132.8 (117.4, 148.3)
	Front	10.8 (5.4, 16.1)	147.3^{c} (139.1, 155.5)	87.7^{d} (97.0, 78.4)	136.5 (124.6, 148.5)
Shoulder abduction					
Male	Behind	54.8* (51.0, 58.7)	124.3 (119.3, 129.3)	98.0 (99.2, 96.7)	69.5* (64.6, 74.3)
	Front	32.8* (28.0, 37.6)	125.7 (120.4, 131.0)	99.0 (99.4, 98.6)	92.9* (85.3, 100.4)
Female	Behind	56.6^{+} (50.4, 62.9)	123.4 (118.5, 128.3)	98.6 (98.4, 95.1)	66.8^{+} (60.8, 72.8)
	Front	33.4^{+} (27.1, 39.7)	124.7 (121.0, 128.3)	98.4 (99.7, 97.2)	91.3^{+} (84.0, 98.6)

$p < 0.05$, significant difference when comparing measures where same superscript letter or symbol is used.
A superscript letter is used to compare gender and a superscript symbol is sued to compare techniques with the same gender.

facing, or perpendicular to, the barbell (Table 2). During behind the head condition males (24.7°) achieved a significantly ($p < 0.001$) greater range of rotation than in-front of head orientation (6.0°). For females range of cervical rotation differed little between behind the head (14.0°) and in-front of head conditions (11.0°).

All subjects commenced the ascent phase of the overhead press, for either technique, in an extended thoracic spine position. The thoracic spine stayed mostly in an extended position for both techniques, albeit on occasion approaching an almost flat position. Behind the head overhead press appears to produce less thoracic extension than in-front of the head (Table 3). Generally the behind the head technique commenced with a lower degree of thoracic extension than the in-front condition. Throughout the overhead press the thoracic spine remained in an extended position and moved between 12° and 15°, regardless of gender or type of press. Males were able to maintain some form of lumbar lordosis, whilst females lumbar spine was placed in mostly an anterior flexed or loss of lordosis (Table 3).

Lumbar measures differed between genders, with significant differences across a range of lumbar spine measures. However, the range of change found in lumbar flexion was similar with measures of between 8° and 10°. During the course of the overhead press for both behind and in-front of head conditions, males were able to maintain almost a flat or normal lumbar lordosis, whereas females tended to become kyphotic during both overhead press movements. The maximum angle of lumbar flexion and the time at which the lack of lordosis was at its greatest anterior flexion occurs mostly about the middle of the overhead pressing movement.

Initial measures for passive shoulder flexion in the supine position show the ROM was less than suggested ideal of 180°, with males scoring 159° and females 168°. Behind the head overhead press moved the shoulder through a ROM that was less than both passive shoulder flexion and shoulder abduction ROM (Tables 4 and 5). Passive shoulder flexion ROM had several moderate correlations with spine measures. In particular minimum thoracic flexion ($r = 0.471$), and minimum lumbar flexion ($r = 0.576$) had positive correlation with passive shoulder flexion ROM. The maximum abduction angle achieved for both genders and type of overhead press differed by around 2° and was more than 40° less than full passive ROM. Similarly passive shoulder horizontal adduction ROM was −28° for males and −33° for females. This ROM result for both genders was well behind the frontal plane.

Initial passive ROM for external rotation was less than 90° for both genders reaching 85° for males and 89° for females. The behind head technique took the shoulder into a more externally rotated position than the in-front technique (Tables 4 and 5) at the start with 26° greater rotation for males and 35° for females. However the behind head technique for males had an average start position of 92° external rotation which was greater than the average passive ROM of 85°.

Table 5
Shoulder rotation and horizontal adduction presented as mean (95% CI) for gender and overhead press technique.

		Start position (degree)	Minimum (degree)	Minimum time (%)	Range (degree)
Shoulder external rotation					
Male	Behind	92.3^{b}* (87.6, 96.9)	36.5^{b}* (29.2, 43.7)	97.5^{b} (98.2, 96.8)	56.3* (49.3, 63.4)
	Front	66.5^{e}* (63.0, 70.1)	25.3^{e}* (20.9, 29.7)	96.0 (99.4, 91.4)	42.5^{e}* (37.7, 47.2)
Female	Behind	79.3^{b+} (73.6, 84.9)	25.9^{b+} (18.1, 33.6)	93.5^{b} (97.3, 89.7)	53.5^{+} (48.3, 58.7)
	Front	44.5^{e+} (41.8, 47.1)	13.5^{e+} (9.3, 17.7)	87.7 (96.7, 78.7)	32.8^{e+} (29.9, 35.6)
Shoulder horizontal adduction					
Male	Behind	65.7 (54.5, 76.8)	34.8 (25.7, 43.9)	92.6 (99.4, 85.8)	32.1 (26.4, 37.7)
	Front	61.7 (52.1, 71.2)	37.5^{f} (29.9, 45.1)	92.1 (99.6, 83.9)	28.9^{g} (24.0, 33.7)
Female	Behind	57.4^{+} (51.5, 63.4)	32.1 (26.5, 37.8)	92.3 (99.8, 86.4)	28.0^{+} (22.5, 33.5)
	Front	69.7^{+} (65.9, 73.5)	31.1^{f} (26.6, 35.6)	96.5 (98.2, 94.8)	39.1^{g+} (35.2, 43.0)

$p < 0.05$, significant difference when comparing measures where same superscript letter or symbol is used.
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4. Discussion

The aim of this research was to determine the impact of behind the head or in-front of the head overhead pressing technique on shoulder range-of-movement and spine posture. The in-front of head technique commenced the press in a lordotic position (males −8.5° and females −8.4°), and behind the head commenced in a kyphotic position (23.9°, 17.1°). The kyphotic commence position for the behind the head was likely due to the participant moving the head forward to allow clearance for the bar to move from behind the head to above the head. When pressing to the cervical spine commences with a more normal lordosis again to allow the bar to travel vertically from the in-front position to overhead. During the movement both types of overhead pressing caused the cervical spine to move into a more flexed position.

Research into cervical and thoracic postures have suggested that more neutral postures may reduce cervical spine loading and forward head posture may induce increased loads into the cervical spine.[28] Due to the need to move the head either forwards or backwards, to allow vertical trajectory of the bar, the resultant changes in cervical curvature occurred at different times during the press. Interestingly the range of cervical flexion was significantly different between genders, with males achieving 42.5° and females only 16.8° in behind the head ($p = 0.05$), and 18.7° and 24.4° respectively for in-front of head ($p < 0.01$). It appeared that males adjust the cervical spine more in overhead pressing, especially behind the head technique, in comparison to females. This forward head adjustment seen in the behind the head technique may increase the loads into the cervical spine and should be considered when prescribing the behind the head exercise technique to people with existing cervical spine pathology.

Cervical rotation also occurred during both forms of the overhead press. During in-front of head technique normal cervical rotation occurred, and when placed behind excessive rotation occurred that are not related to normal flexion extension of the cervical spine. Previous research showed that during normal flexion extension movements of the cervical spine, a small amount of up to 5.0° cervical rotation occurred.[29] The authors suggest this was related to moving the head to allow a more vertical pressing action allowing the bar to clear the rear of the head.

Normal thoracic kyphosis has been identified at 26° in previous research.[30,31] The results from the current study show that in both males and females, both forms of overhead pressing cause extension and flattening of the thoracic spine. In previous research tracking thoracic spine movements, thoracic extension was found to occur when the arm was elevated through shoulder flexion.[32] This matches the results found in the current study, where regardless of the order of the movements, thoracic extension occurred during the overhead pressing movement as a coupling action with the shoulder movements. Whilst the arm elevation was unloaded and light in comparison to the 3RM loads in the current study, this suggested there was an association between moving the arms overhead and thoracic extension. This may become more evident due to the increased loads used in the current study. This relationship may occur so as to require the muscles of the anterior chest and shoulder to become more involved in the overhead press. A more slouched thoracic posture has been previously associated with a loss of overhead force,[31] by extending the thoracic spine the glenohumeral joint and scapula become more anatomically orientated to press overhead and may support increased overhead force output.

Differences between genders in lumbar behaviour have been reported previously for back squatting where the loaded bar rested across the shoulders.[33] The current study supported this finding and suggested female subjects were less able to maintain normal lumbar flexion during overhead pressing with 3RM loads. This may be due to a reduced or different trunk muscle function, and suggests females are less able to maintain normal spine posture when overhead pressing. Many overhead sports movement patterns such as throwing, spiking, serving, and pitching involve arching of the back as a precursor to the movement during the 'wind up'. Evidence exists to show the trunk musculature activates to support the lumbar spine during the back-arch and service action in tennis,[34] and a high degree of neuromuscular coordination between the upper and lower body in overhead sports that result in spine extension.[35–37] This spine extension appeared to also exist for overhead strengthening exercises as shown in the current study and appears to be an important part of overhead work.

Multiple correlations were evident between the three segments of the spine, indicating a change in the flexion angle in one segment was associated with a change in the flexion of the other two. This was most evident in the relationship between the lumbar and thoracic spine, where the start angle of the thoracic spine correlated with lumbar flexion start angle (behind the head $r = 0.779$, in-front of the head $r = 0.670$) when genders were combined. Behind the head technique found correlations between all three spinal segments whereas in-front tended to show more correlations between the thoracic and lumbar as the cervical spine was less likely to move as the movement of the bar altered cervical spine position less than behind the head technique. In overhead pressing it appeared the spine behaved in a complete, rather than segmental manner, to adjust its position and allow the overhead press movement to occur.

All dynamic shoulder flexion ROM for both genders were close to, but did not exceed passive ROM. This may also reflect on the extension relationship discussed previously on the spine. This showed if an individual has a greater passive shoulder flexion ROM, they are less likely to extend the spine to get the bar overhead, as the shoulder ROM allowed this to occur without the coupling movement of spine extension. This reinforced the need for participants to maintain optimal ROM in shoulder flexion if their sport or rehabilitation requires overhead pressing strength work. A decrease in spine extension, and change in flexion-extension of the spine, during overhead lifting will create a more stable spine and platform from which to develop overhead strength.

During the overhead press the shoulder was never close to passive ROM for horizontal adduction let alone behind the frontal plane with most achieving 30° in front of this plane in line with the accepted scapular angle of 40°.[38] At this point it must be noted that overhead pressing either in-front or behind the head technique do not take the shoulder joint close to passive ROM measures and appeared to be well within mean vales achieved for ROM for the shoulder in this cohort.

Shoulder rotation measures were taken initially in supine, hence the "high-five" position where the arm was externally rotated to 90° and the elbow bent to 90°, similar to the position seen in overhead pressing. The position during the overhead press when the shoulder was taken to the most externally rotated position was at the bottom, or the start, of the ascent phase. This was the only occurrence of the dynamic range being greater than the passive ROM found during this study. During this phase of the movement most effort was required to initiate the upward movement, this may cause undue stress into the shoulder of males who have a reduced ROM in external rotation. The authors suggest that before including behind the head technique in a strength program, an assessment of ROM followed by a program to increase ROM in this direction before this style is utilised. However in-front technique for both genders did not take the shoulder close to the passive ROM for external rotation. This research showed that with the exception of external rotation in males when pressing behind the head, all passive ROM for shoulder are not exceeded by the dynamic motion of overhead pressing.

Finally the multiple correlations for height, arm span and bi-acromial width with spine segment angles and 3RM loads suggest that there is a definite interaction between these areas that must be considered when prescribing the overhead press. Taller people tend to alter thoracic and lumbar curves more than shorter people and techniques associated with overhead pressing for taller people should be developed with specific cues associated with spine control and stability to avoid risk of injury from excessive lumbar or thoracic flexion.

The authors acknowledge that muscle activation patterns may also change with overhead press techniques and future research may include the use of electromyography to report muscle activation of both the trunk and shoulder regions to provide further insight into patterns of movement of these regions.

5. Conclusion

Overhead pressing in a seated unsupported position requires good trunk control to stabilise the posture of the spine. Females showed greater spine movements, suggesting a trunk strengthening program prior to including overhead pressing may be beneficial. The dynamic external rotation ROM for males was greater than their passive measure for behind the head protocol. To avoid possible injury passive ROM should be increased prior to behind the head protocol. For participants with normal trunk stability and ideal shoulder ROM, overhead pressing is a safe exercise (for the shoulder and spine) when performed either in-front or behind the head.

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