Journal of Novel Physiotherapies

Kour, et al, J Nov Physiother 2014, 4:5
http://dx.doi.org/10.4172/2165-7025.1000236

Research Article Open Access

# Variation in the Kinematic Response of Cervical Spine, Proprioception and Muscle Activity During Anterior Load Carriage-An Experimental Study

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**Received date:** October 28 2014, **Accepted date:** November 29, 2014, **Published date:** December 6, 2014



## Abstract

**Background:** Front load carriage is a common occupational task in some industries (e.g. agriculture, construction). Previous studies were conducted to examine the effects of load carriage on changes in thoracic and lumbar spine rather than the effects on the cervical spine. The focus of this study was to explore kinetic and kinematic response of cervical spine the during anterior load carriage and, specifically, to examine the effects of load height on neck muscle activity and neck posture. Despite the evidence linking between load carriage and kinetic and kinematic response, previous studies to examine lumbar spine rather than the effects on the cervical spine.

**Methodology:** 30 female participants participated in this front load-carriage experiment. The experiment called for carrying a barbell (with weight corresponding to 10% of body weight of the participant) at three heights (knuckle height, elbow height and shoulder height) at a constant horizontal distance from the spine. In this experiment, the participants performed this task while standing still. As they performed this task, the activity level of the upper trapezius was sampled. Craniovertebral angle and proprioception of cervical spine were also quantified using photographic method and magnetic inclinometer respectively at these three heights.

**Results:** The results showed a significant effect of load height on muscle activity, craniovertebral angle and proprioception (flexion) of cervical spine levels in the barbell experiment but insignificant effect for proprioception (extension) of cervical spine.

**Conclusion:** These results provide insight into muscle activation patterns, proprioception and kinematic response of cervical spine especially (load) carrying biomechanics, and have implications in industrial settings that require workers to carry loads in front of their bodies.

**Keywords:** CVA; Proprioception; EMG; Front Load carriage

## Introduction

Load carriage or manual material handling work activities, such as lifting and carrying allows an individual to transport an additional mass whether it is on the anterior aspect, posterior aspect, or sides of the body, or through the use of a carrying device and these have been found to be associated with low back problems [1]. Front load carriage is a common occupational task in some industries (e.g. agriculture, construction) and maximum studies has been conducted on the biomechanical challenges of lifting tasks [2], much less study has been conducted on the biomechanical challenges of anterior load carriage in occupational settings [3]. ‘Anterior load carriage’ is specified to distinguish it from posterior load carriage, as a lot of study has been done in this field [4]. A review of a number of psychophysical studies were presented that considered carrying activities and the reviewed studies examined a variety of factors including carrying mode and height, walking speed, time and distance [3]. Of particular relevance to the current study data were generated by Snook [5], in which two different heights were considered at which a load was held (approximately elbow height and knuckle height). It was shown that psychophysically determined maximum acceptable weights of carry were, on average, 26% (range 14–42%) more at knuckle height than at elbow height. The subsequent work of Snook and Ciriello [6] supported these results.

Researches have considered that a minimum amount of stress on the body can be achieved by proper musculoskeletal balance that requires proper posture Yip et al. [7], this desired posture is not often exhibited by the general population. Chiu et al. [8] has noticed forward head posture in patients with neck disorders and along with neck flexion is thought to be a risk factor for neck pain. Yip et al. [7] considered the craniovertebral angle to investigate the head posture with pain.

Studies have been carried out by Amal H Ibrahim [9] to determine effect of a school backpack on the musculoskeletal health of children and adolescents. Vacheron et al. [10] used radiographic methods to investigate the effect of backpack on the intersegmental mobility. According to Heather Brackley [11], there is an increasingly pronounced surface curvature of the thoracic and lumbar spine after load carriage by using a backpack instrumented with spring-loaded potentiometers. Holmes [12] evaluated rather than simply the change in sensory information caused by the carriage of the backpack itself, the immediate changes in spinal curvature caused by carrying loaded backpack appears to have a direct effect on the repositioning errors. Mehrshed Sinaki [13] noted that the posture adopted has an effect on the repositioning error and, as carriage of the loaded backpack causes changes in the spinal posture, this may be related to the changes in repositioning consistency observed 8. Most of the studies were done to determine the effects of posterior load carriage and the effects were seen on the thoracic and lumber regions of the spine but very few studies were done to determine the effects of anterior load carriage on the cervical spine.

Researches by Knapik et al. [14] have evaluated that the energy consumption, spinal loading and coactivation of trunk muscles are effected by the speed of the individual, load weight and height. Bobet and Norman et al. [15] evaluated the interaction between the load height and walking speed by studying the electromyographic (EMG) activity of the trapezius and erector spinae muscles under static conditions and dynamic conditions by placing the load on the back in the cervical and upper thoracic region. Researches by Ashish D Nimbarte et al. [16] have evaluated the sensitivity of trapezius to neck posture and weight lifting.

The literature detailing the biomechanics of anteriorly located loads is less expansive and has often been focused on comparing anterior loading with other load carriage locations or has been considered under static weight- holding conditions with the goal of assessing spinal stability. The neuromuscular response to changes in spinal stability was demonstrated by finding out EMG activity increased in the trunk muscles as the height of the load was increased in front of body [3]. While this research provided an important detailed assessment of trunk muscles not about the neck muscles, muscle activation profiles during dynamic load carriage would be helpful to understand the risks posed.

The objective of the present study was to evaluate the effects of anterior load carriage on the kinetic (muscle activity) and kinematic response of cervical spine of human participants during a weight-carrying task with particular emphasis on load grip height.

## Method

### Participants

A total of 30 healthy female participants aged from18 to 26 years were included in this experiment. Exclusion criteria were any neurological or degenerative condition that affects the muscle activity and proprioception. The whole study was conducted with the permission of institutional ethical committee for using human subjects as a sample and a consent form was signed from each individual. All the subjects were collected using randomization method. The independent variable in this experiment was load grip height measured at three levels viz. knuckle (arms fully extended downward), elbow, and shoulder heights. Outcome measures were EMG data for the upper trapezius, the craniocervical angle and proprioception of cervical spine.

### Experimental procedure

An experimental setup was formed which consist of a platform on which subject has to stand and carry a defined load, an EMG apparatus to measure the muscle activity and a stick to measure the level of load height.

Prior to participation each subject was given instructions that how she has to lift the barbell that would be used for the lifting trials of the study.

The barbell was 15 inches long and was equipped with a measuring stick to allow the researchers to ensure that a constant moment arm of the barbell was maintained about the spine. Because of this level of control, the barbell experiment represents a more controlled study of the response of the cervical region. The weight of the barbell corresponded to 10% of body weight of the participant.

### Measurement of EMG

Surface electrodes were applied to the skin over the trapezius muscle using standard preparation techniques so that the two electrodes ran parallel to the muscle fibers of trapezius and positioned so that 1 electrode was superomedial and 1 inferolateral to a point 2 cm lateral to one-half the distance between the C7 spinous process and the lateral tip of the acromian [17].

Prior to measure the EMG data subjects were instructed to remove their hair to improve the adhesion of the electrodes, especially under humid conditions or for sweaty skin types and/or dynamic movement conditions and clean the skin with pure use of alcohol to reduce the skin resistance.

All the participants were instructed to stand on floor with carrying a loaded barbell according to their body weight and perform a series of weight-holding task.

During these trials, the barbell was held at the level of knuckle, elbow or shoulder height while standing still, activity was performed by the participant one time for an each three position. The data collection period lasted for 6 s for these trials.

The muscle activation data collected through shielded cable to the main amplifier (Neuroperfect EMG/ NCV/ EP system, EMG-200). In default the settings for sensitivity, filters, sweep speed etc are as follows sweep speed as 20 ms, sensitivity as 200 micro volt, Hi filer as 5 KHz, Lo filter as 100 Hz, Notch filter as On. From the recorded signals, peak to peak amplitude (PTPA) was measured.

### Measurement of proprioception

Proprioception was measured through magnetic inclinometer for neck movement. Every patient was placed standing and the magnetic inclinometer was affixed to the patient's forehead.

The inclinometer was positioned in such a way that the centre of inclinometer was in alignment with the tragus of the ear (Figure 1). Patients were instructed to close their eyes, nod a few times and then return the head in the complete resting position.

Their head was then positioned at 30 degree of flexion and then return to 0 degree with eyes closed.

The patients were then asked to reproduce the angle 3 times with eyes closed within a 60 second period and the inclinometer reading was noted (Figure 2).

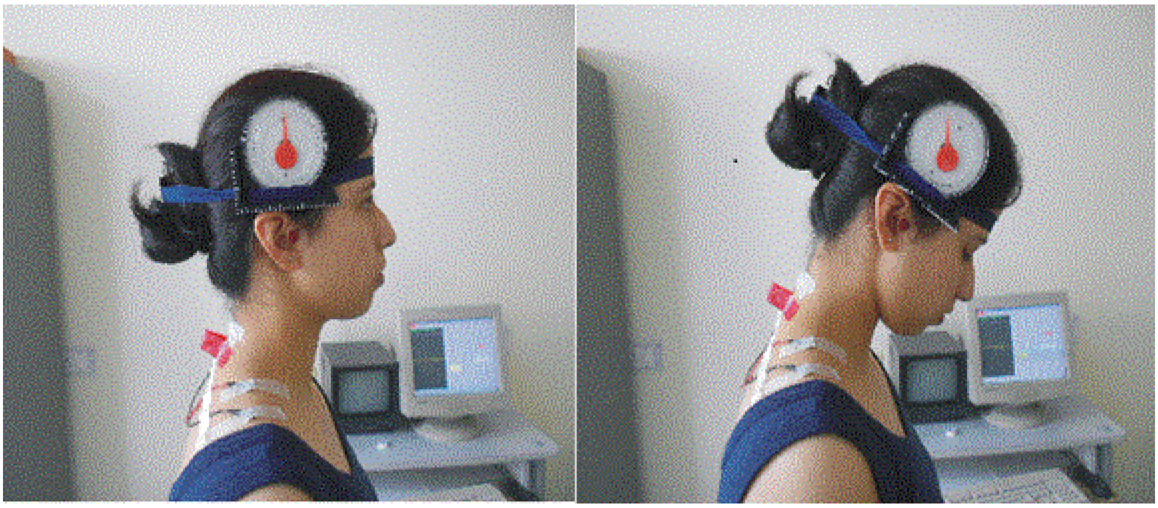

**Figure 1:** Measurement of proprioception during anterior load carriage.

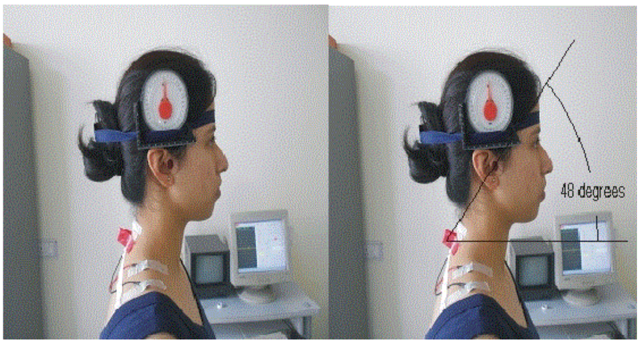


**Figure 2:** Measurement of craniovertebral angle.

### Measurement of craniovertebral angle

Craniovertebral angle was measured through photographic method. Tragus of the ear and C7 spinous process was identified for measurement of the angle. To locate the spinous process of C7, subject is asked to flex and extend the neck and palpate the more prominent spinous process. Clay was put on C7 spinous process so that it would become visible on photograph. Nikon digital camera was mounted on a tripod stand and kept 2 meters away from the subject. The camera was placed at the level of shoulder by adjusting the height of the tripod stand leveling with spirit level [18]. Then lateral view of the patient was taken on photograph. The measurements of craniovertebral angle were done using COREL DRAW 12 software.

## Data Analysis

Data was analyzed using statistical Software package of SPSS 17. ANOVA test was used to analyse the effects of load height on EMG, CVA (Figure 3)and proprioception at three different heights. In only those cases where the ANOVA test showed a significant effect a post hoc analysis was used using tukey's HSD (Honestly significant differences) test. p- value was set at 0.05 for denoting significant effect (Figure 4).

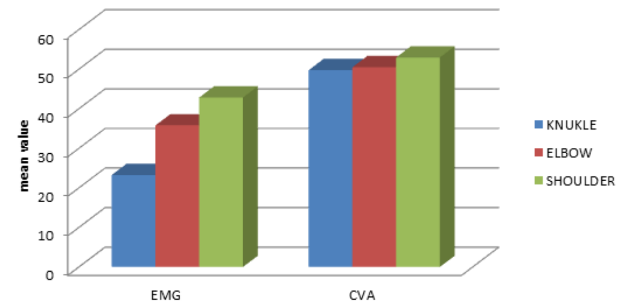


**Figure 3:** Mean comparisons of EMG and CVA

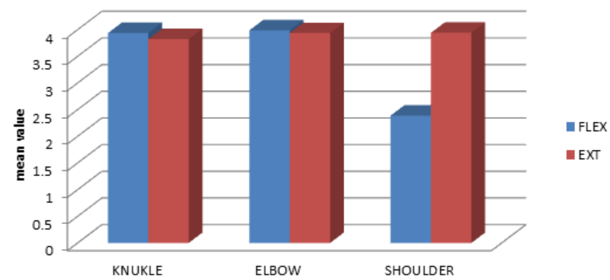


**Figure 4:** Mean of proprioception

## Results

ANOVA test was found significant for electromyography, craniovertebral (CVA), proprioception (flexion) -with a p value of 0.0001, 0.007, 0.012 respectively but it was found insignificant for proprioception (extension) with a p value of 0.978 when the load was lifted at all the levels viz. knuckle, elbow, and shoulder (Table 1).

| | EMG | CVA | Prop – Flex | Prop – Ext |
|---|---|---|---|---|
| F Value | 10.512 | 5.088 | 4.579 | 0.023 |
| p value | 0.0001 | 0.007 | 0.012 | 0.978 |

**Table 1:** ANOVA within groups

Tukeys HSD found significant results for electromyography at knuckle vs elbow, elbow vs shoulder and shoulder vs knuckle with a mean difference of 125.43, 70.32 and 195.75 respectively. In craniovertebral angle the mean difference is 0.74, 2.48 and 3.23 respectively, for proprioception in flexion it is 0.04, 1.59 and 1.54; for proprioception in extension it is 0.1142, 0.006 and 0.12 respectively (Table 2).

| | | EMG | CVA | Flex | EXT |
|---|---|---|---|---|---|
| Knuckle Vs Elbow | Mean diff SEM | 125.43 ± 43.25 | 0.74 ± 1.06 | 0.04 ± 0.60 | 0.1142 ± 0.63 |
| | P value | 0.012 | 0.76 | 0.996 | 0.982 |
| Elbow Vs Shoulder | Mean diff SEM | 70.32 ± 43.25 | 2.48 ± 1.06 | 1.59 ± 0.60 | 0.006 ± 0.63 |
| | P value | 0.238 | 0.053 | 0.023 | 1 |
| Shoulder Vs Knuckle | Mean diff ± SEM | 195.75 ± 43.25 | 3.23 ± 1.06 | 1.54 ± 0.60 | 0.12 ± 0.63 |
| | P value | 0 | 0.08 | 0.029 | 0.981 |

**Table 2:** Post Hoc Analysis (Multiple Comparison) within the groups

## Discussion

Most of the archival literature on the biomechanical responses during load carriage is focused on posterior load carriage and is limited to understand the stress during carrying work activities. Anderson et al. [3] did a study on a biomechanical analysis of anterior load carriage but the focus of that study was to explore the low back biomechanics during these load activities and specially to examine the effects of load height and walking speed on trunk muscle height and trunk posture but the study had not examined the effect on muscle activity of the neck muscle, cervical spine biomechanics and proprioception. As frequent material activities found in construction work environment were found to put substantial stress on the neck, shoulder and lower back resulting pain and discomfort [19]. There was also found the changes in spinal curvature and proprioception of school boys carrying different weights of backpack [12]. Therefore, the present study was designed to provide some quantitative data to explore the cervical spine biomechanics during the anterior load carriage and specially to examine the effects of one carrying task design parameter that is load height on neck muscle activity, proprioception and neck posture.

The contribution of muscles of cervical spine was evaluated during anterior load carriage in this study as Swedish construction workers studied by Holm storm et al. [20] among whom 41% had neck and shoulder disorders. Ashish D Nimbarte et al. [19] also studied role of neck muscles during lifting and holding tasks at shoulder height.

Neck and shoulder disorders affect 23.6% of male and 32.1% of female among Taiwanese construction workers by Guo11 et al. which supported the selection criteria for female subjects in this study. In girls the prevalence of neck pain increase with age [21].

In this study normal healthy individuals were selected. The individuals with history of cervical and low back pain were excluded because the differences in proprioception in individuals with back pain and those free from back pain were found [22]. Also there was found relationship between head posture and severity and disability of patients with neck pain [7]. Also a positive and significant relationship between pain intensity and superficial muscle activity was shown [23].

Chris Ho Ting et al. [7] measured forward head posture through craniovertebral angle to find the relationship between head posture and severity and disability of patients with neck pain. Shivananda et al. [24] also analyzed cervical and shoulder posture in school children using back pack experiments study in which craniovertebral angle, shoulder saggital posture angles, craniovertebral angles were calculated. June Quek et al. [25] assessed forward head posture through craniovertebral angle to explore the mediating effects of forward head posture on relationship between thoracic kyphosis and cervical mobility in older adults with cervical dysfunction.

In this study anterior load carriage at three different levels had a significant effect on the craniovertebral angle that the craniovertebral angle was increasing with the load height. This can be explained by the fact that it occurred in order to compensate to the posterior shift of the trunk. The posterior shifting of the trunk to shift the centre of the new loaded system to a more balance location was noted by Anderson et al. [3] who found a significant effect of load height on the saggital angles at T9 and T12 levels. Shoulder height load carriage resulted in larger postural deviation than carriage at the lower heights. It has also been shown that there is an increasing trunk inclination and increasing head on trunk extension with increasing back pack load Chow et al. [12].

The upper trapezius muscle, especially along the C7 level, has been widely studied in occupational investigations to evaluate the neck disorders. To our knowledge, no previous study evaluating occupational tasks involving anterior load carriage has reported the activity of upper trapezius in the cervical region while evaluating biomechanical analysis. Understanding the activation of this muscle is vital, as it is bigger (surface) muscle in the neck region and anatomically connects the shoulder to the skull. Such an anatomical orientation may require this muscle to support the shoulder during anterior load carriage. The results of this study clearly show that upper trapezius was sensitive to lifting weight and there is increase in activity of upper trapezius muscle. The posture had a significant impact on the activation level of the neck muscles and the upper trapezius muscle was most active at the flexed neck posture [19]. As an increase in craniovertebral angle with an increase of load height was found in our study, this explained the increase in activation of upper trapezius with increase in load height. It has also been shown that under dynamic conditions, placing the load in the C1-C7 region created significantly higher level of muscle activity for both trapezius as compared to those captured at T1-T6 region [15]. Over all, the result of this study indicated that trapezius muscle play an important role during lifting and holding tasks.

It has been shown that there is a decrease in repositioning consistency of the lumbar spine with the increasing back pack load [12]. The results of this study showed that there is maximum decrease in proprioception of the cervical spine at shoulder level but there is slight increase in proprioception at elbow level as compared to the knuckle level. Study by James E carpenter et al. [26] showed that proprioception is diminished in the presence of muscle fatigue, also dorsal neck muscle fatigue alters cervical position sense [27]. This alteration in the fatigue muscle was due to the metabolites and / or inflammatory substances as in the fatigued muscle the nociceptors are activated by the end metabolic products (including bracykinin, arachidonic acid, prostaglandin E2, potassium, and lactic acid), which were produced during the previous muscular contractions. These metabolites and/or inflammatory substances within the muscle during fatiguing exercise modify the proprioceptive input by increasing the threshold for muscle spindle discharge [28-30]. Another study done by Anderson et al. [3] found increased activity of anterior deltoid and erector spine when the load was lifted to the level of shoulder height. The results of this study showed increased activity of trapezius muscle when the load was lifted to the level of shoulder height. As there was more of muscular activity at the shoulder level when the load was lifted up to this level, this had resulted in more production of metabolic products. This explained the decrease in proprioception of cervical spine at shoulder level.

Posture affects muscle activation. Ashish D Nimbarte et al. [19] found that during neck flexion trapezius is active and during neck extension sternocleidomastoid is active. As in this study anterior load carriage caused flexion of neck, so at that time trapezius was most active but not the sternocleidomastoid because no natural extension of neck was there. This explained that why the results of neck proprioception in extension were varied in this study.

This study had several limitations that need to be considered. In actual, occupational sites have harsh outdoor environments due to noise, vibration, space and time constraints that could impose psychological stress which will further effects the muscle activation. Secondly, for standardization purposes, the subjects in this study lifted certain percentage of their body weight. In actual working conditions, regardless of body size or strength the workers lift weight of different sizes and dimensions. Thirdly, relatively younger people with less experience in physical demanding work were tested in this study. Considering the relatively awkward lifting posture tested in this study, the ability of the participants at three different levels might have been less than actual load carrying workers. Moreover, it is possible that the muscle activation pattern in experienced workers may be different than the relatively in experienced subjects. The results obtained in this study solely on female participants may not equally to males. Diet, hydration status of the subjects was not considered in this study.

This study considered the relatively under-explored area of anterior load carriage. Workers in the agriculture industry perform a significant amount of this type of exertion, and understanding the effects of load height may help ergonomists develop appropriate ergonomic interventions for the prevention of neck injury and fatigue.

The future study can be recommended on symptomatic subjects to compare and to see the effects. The study can be recommended to evaluate effect of walking speed on muscle activation patterns, proprioception and kinematic response of cervical spine.

## Conclusion

These results provide insight into muscle activation patterns, proprioception and kinematic response of cervical spine especially (load) carrying biomechanics, and have implications in industrial settings that require workers to carry loads in front of their bodies.

## Acknowledgement

Inderjeet kour- Mother, Jasbir Singh- Father, Dupinder kour-Sister.

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