

# Is There A Compensatory Inverse Association Between Standing Anterior Pelvic Tilt and Craniovertebral Angles when Heavy Backpack Loads are Imposed Onto The Vertebral Colum?

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DOI: [10.36348/jaep.2021.v05i03.005](https://doi.org/10.36348/jaep.2021.v05i03.005)

| Received: 25.01.2021 | Accepted: 03.03.2021 | Published: 30.03.2021

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## Abstract

Scholars carrying heavy backpacks incur misaligned vertebral posture and neuro-musculoskeletal discomfort and pain. This report intends to determine whether there is a compensatory inverse relationship between standing anterior pelvic tilt (SAPT) and craniovertebral angles (CVA) when heavy backpacks are carried. A male pubescent carried a backpack weighing 6.2kg (17.3% of his body mass) over both shoulders resting against his vertebral column. The pubescent CVA, SAPT, standing vertex height (SVH) was measure during unloaded, and three loaded phases. Each loaded phase approximately increased from 10%, 20% and 30% of the pubescent's relative body mass. The incremental backpack masses reduced the SVH and increased the SAPT, while simultaneously reducing CVA. There was a positive relationship between increased backpack mass and SAPT ( $r=+0.9$ ). Craniovertebral angle inversely attenuated in response to the heavy backpack loads ( $r=-0.9$ ). These findings indicate that there is an inverse compensatory relationship between SAPT and CVA when carrying heavy backpacks.

**Keywords:** Anterior pelvic tilt, backpack, craniovertebral angle, scholar.

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## INTRODUCTION

The habitual carrying of backpacks by scholars of all ages has emerged as a societal occupational concern due to the compensatory musculoskeletal ill effects [1, 2]. Voll and Klimt's [3] rule of thumb prescribed scholars to carry a maximum of 10% of their respective body mass in an attempt to prevent these musculoskeletal ill effects. Steele *et al.*, [4] and Sahib [5] have supported this recommendation, but it has been repudiated by Brackley and Stevenson [6] who recommend a load of 15%. The musculoskeletal occupational concerns include misaligned vertebral posture, neuro-musculoskeletal discomfort and pain resulting in the absence from scholastic and physical activities [1-6]. The misaligned vertebral posture relates to excessive cervical and lumbar lordosis and thoracic kyphosis [7, 8]. Heavy backpack carriage does produce serial distortion of the vertebral column referred to cervico-kypholordotic posture [9]. Cervico-kypholordotic posture is the compensatory misaligned vertebral column, having an enlarged cervical lordosis, thoracic kyphosis and lumbar lordosis. Walikca-Cupyrts *et al.*, [10] postulated that heavy backpack carriage initiates an anterior pelvic tilt, which is an attempt of

the musculoskeletal system to accommodate the heavy external load carried. The compensatory pelvic rotation impacts on the anterior-posterior weight supporting structure of the vertebral column that has been associated with neuro-musculoskeletal discomfort and pain. There has been numerous studies documenting the change in SAPT [10, 11] and CVA [12, 13], but, there is a paucity of literature identifying the compensatory relationships among the increasing external backpack loads with changes to SAPT and CVA. This case study intent to document whether a compensatory relationship exists between the magnitude of SAPT and CVA deviations due to carrying various external backpack loads of different masses.

## METHODS

### Participants

The parent of a male scholar (12 years old) reported that the pubescent displayed a misaligned posture when carrying his school backpack bag [9]. This case study reviewed the six-month progress report post the initial biokinetic consultation and rehabilitative exercise prescription. The scholar indicated that heavier the external mass of the backpack, the greater the lower back and shoulder discomfort he experienced. The

parent also indicated that heavier the backpack the greater the sagittal plane postural deviation. The pubescent's parent brought the scholar in for a six-month post rehabilitation posture analyses consultation. Biokinetics is an exercise therapy vocation that prescribes physical activity and exercises to manage various pathologies [14]. Both pubescent and parent provided child ascent and parental informed consent.

### Procedure

The pubescent's kinanthropometrical measures (body mass and SVH), school backpack and biomechanical angles (CVA and SAPT) were measured in the unloaded phase (not carrying backpack) and then during the loaded phases (carrying the backpack). The loaded phase consisted of three trials of different external backpack loads, approximating 10% incremental loads.

The kinanthropometrical measures were recorded as per International Standards for Kinanthropometric Assessments [15]. The biokineticist used Hande *et al.*, [16] protocol to record the pubescent's CVA, and the Starkey's [17] protocol to quantify SAPT. The reduced CVA suggested altered cervical vertebral alignment on thoracic vertebrae representing excessive cervical lordosis. The enlarged SAPT indicated an anterior pelvic rotation (short-arc pelvic-on-femur flexion).

### Data Analyses

Included descriptive (mean and standard deviation) and inferential statistical tests (Pearson correlation) to measure the associations among the incremental external mass of backpack load on SVH, CVA and SAPT. The dynamic CVA and SAPT associations were reviewed to determine compensatory serial distortion of the vertebral column due to school backpack carriage.

## RESULTS

Table-1 exhibited the changes in kinanthropometric and biomechanical angles among the unloaded versus the three loaded phases. The school backpack weighed 6.2kg that equates to 17.3% of the scholar's body mass. The scholar carried the straps of the backpack on both shoulders. A Pearson correlation test was conducted to determine the inverse association between increased SAPT and diminished SVH ( $r=-0.8$ ). As the total body mass increased the SVH and the CVA decreased, but SPA increased. There was a positive association between decreased SVH and reduction in CVA ( $r=+0.9$ ) as the total body mass increased. Similarly, there was an inverse relationship between CVA and SAPT ( $r=-0.9$ ) as external backpack mass increased.

**Table-1: Postural changes during unloaded versus loaded phases**

Variables	Unloaded	Loaded phase 1	Loaded phase 2	Loaded phase 3	Mean ( $\pm$ SD)
SVH (m)	1.435	1.425	1.42	1.405	142.1( $\pm$ 1.2)
Body mass (kg)	35.8	39.6	42.9	46.7	41.25( $\pm$ 4.6)
*Total body mass (%)	100	110.6	119.8	130.4	120.2( $\pm$ 60.6)
CVA ( $^{\circ}$ )	48	40	30	24	35.5( $\pm$ 10.6)
SAPT ( $^{\circ}$ )	9	15	28	30	20.5( $\pm$ 10.1)

\* Total body mass = pubescent's body mass + school backpack mass

**Table-2: The associative changes due to increased total body mass on height, CVA and SPA**

Relationships	Pearson correlation value
Relationship between increased total body mass and SVH	-0.9
Relationship between increased total body mass and CVA	-0.9
Relationship between increased total body mass and SAPT	+0.9
Relationship between SVH and CVA	+0.9
Relationship between SVH and SAPT	-0.8
Relationship between CVA and SAPT	-0.9

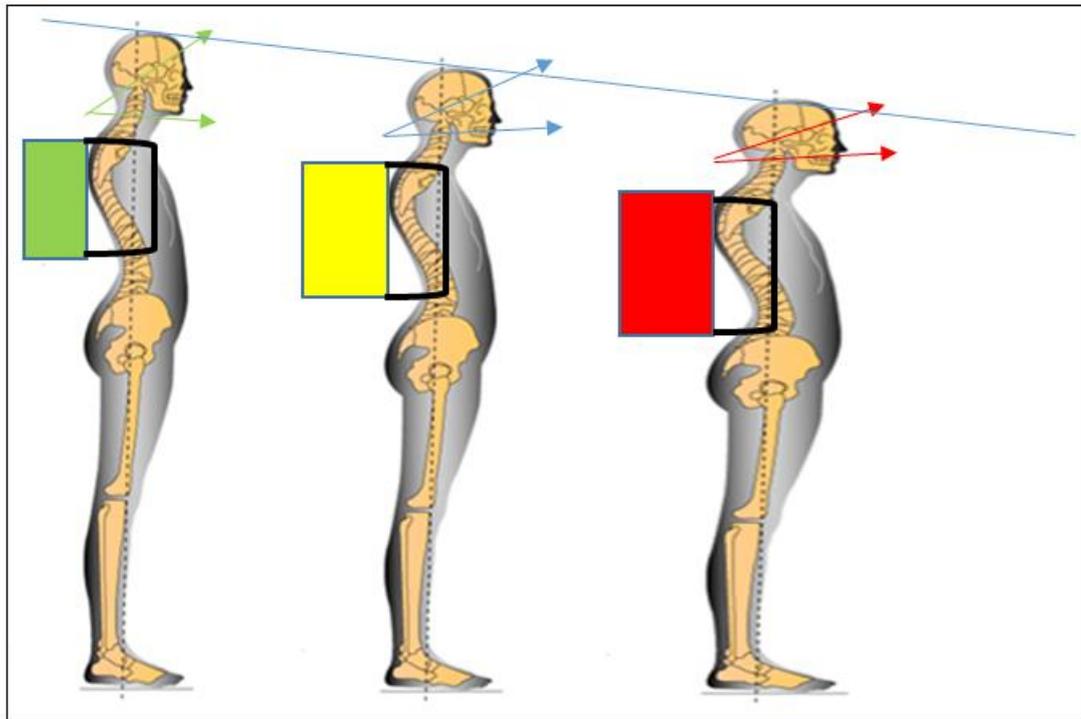
## DISCUSSION

The findings of this report concur with previous literature that heavy school backpack exceeding 10% of the incumbent's body mass does produce misaligned posture evident by the increased SAPT and diminished CVA [7, 8, 12, 13]. The clinical evidence does support the Ellapen *et al.*, [18] premise that heavy backpack loads does diminish the incumbent's SVH. The diminished SVH is due to the reduced CVA and increased SAPT. The evidence does indicate strong relationship between SAPT and CVA

due to the load imposed concurring with Sahib [5]. The pathomechanical cascade of events to achieve this end occurs as follows; increased backpack load anteriorly rotates the pelvis, which produces serial distortion up the closed kinetic chain of the vertebral column resulting a diminished CVA (Figure-1). The inverse reciprocal relationship between increased SAPT and reduced CVA relates to its natural anterior-posterior weight bearing engineering curvature. If the pelvis singularly anteriorly tilted then the pubescent will fall forward as postulated by Ellapen *et al.*, [18]. In order to

prevent a forward fall the thoracic vertebrae hyperflexes and the cervical vertebrae drawn forward thereby diminishing the CVA. In order to maintain an erect posture the craniohorizontal angle is increased. This report indicated that at every 10% incremental

backpack load there is an approximately 7% increased anterior pelvic tilt that produces a compensatory 8% reduction in CVA. The aforementioned biomechanical findings needs to be empirical validated.



**Fig-1: Graphic illustration of the association between increase backpack load and decreases SVH (increasing SAPT and simultaneously reducing CVA) (Paul et al., 2021)**

## CONCLUSION

There is a strong inverse relationship between SAPT and CVA when heavy backpacks are imposed onto the vertebral column.

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