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Comparison of the posture of school children carrying backpacks versus pulling them on trolleys

Johanna Schmidt *, Sharon Docherty

Anglo-European College of Chiropractic, 13-15 Parkwood Road, Bournemouth, BH5 2DF, United Kingdom

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KEYWORDS
Backpack;
Trolley;
Posture;
Gait;
Children

Summary

Objective: To investigate whether there is a difference in the posture of school children walking with a backpack versus pulling a trolley.
Design: Comparative, controlled, pilot trial.
Setting: ''Grundschule Fallersleben'' — primary school in Germany.
Subjects: Thirty-four school children between 6 and 8 years of age.
Methods: Initially, neutral posture was measured in a standing position. All children were then asked to walk a predetermined route without intervention for approximately 7 min. This was followed by walking the same route with either a backpack ($n = 19$) or trolley ($n = 15$). Deviations from neutral of the thoracic and lumbar spine (flexion, extension, lateral flexion and rotation) from the final 30 s of the imaging sequences were taken and analysed.
Results: Compared to unburdened walking, walking with a backpack led to a statistically significant ($p \leq 0.05$) increase in thoracic extension (3.91°, 95% CI = 3.35—4.46) and right lumbar lateral flexion (2.29°, 95% CI = −3.41 to −1.18), and a statistically significant decrease of lumbar flexion (2.2°, 95% CI = 0.34—4.06). In contrast, walking with a trolley increased extension (1.4°, 95% CI = 0.72—2.08), right lateral flexion (1.24°, 95% CI = −1.91 to −0.57) and right rotation (3.09°, 95% CI = −3.85 to −2.32) of the thoracic spine, and led to a statistically significant increase in left rotation (3.57°, 95% CI = 2.58—4.55) of the lumbar spine. Comparing the backpack and trolley groups showed a statistically significant ($p \leq 0.05$) increase in thoracic extension and right lumbar lateral flexion in the backpack group. Posture during trolley pulling was characterized by a statistically significant ($p \leq 0.05$) increase in right thoracic and left lumbar rotation.
Conclusion: Participants adopted asymmetric postures during walking with a backpack and pulling a trolley. However, the trolley group was characterised by spinal rotation which possibly adds an extra source of stress. This suggests that school children should use backpacks rather than trolleys when the weight is within recommended limits.

* Corresponding author. Tel.: +49 1637334221.
E-mail addresses: schmidtj@aecc.ac.uk, chiropraktik@mailanschmidt.de (J. Schmidt).

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Introduction

Back pain is a topic of growing concern in children and adolescents. Pascoe et al.[1] reported the prevalence of back pain in adolescents as high as 51% while Brackley and Stevenson[2] found that the overall lifetime prevalence of low back pain in children is as high as 65%. In Germany and Europe, this, amongst other things, has been linked to backpacks which are too heavy and carried inappropriately[3]; however, research findings have been contradictory.[4,5]

The weight of backpacks varies by the day of the week, the school's teaching concepts and the pupils themselves[6] and reported average weight varies to a large extent in the literature. However, the majority of studies show that the loads carried by school children are greater than recommended limits.[2] The highest reported daily load in children's backpacks represented 46.2% of their bodyweight (BW)[6] compared to a load of <10% BW found by Forjuoh et al.[7] Based on the current literature on backpack use, injuries and biomechanical changes related to weight of backpacks, recommendations for weight limits were formulated by various researchers.[2] They agreed that the load should not exceed 10–15% BW.[2,5]

A trend has developed in Germany over recent years where backpacks have been increasingly used in conjunction with trolleys — a device which allows the child to pull their backpack behind them. Little research has been conducted investigating the effects of pulling a trolley on gait and posture in children; however, observations of the child's posture during this activity raise questions about any advantage they have over carrying backpacks.

The aim of this study was to investigate the postural effects of walking with a backpack compared to using a trolley.

Methods

Subjects

Subjects were pupils in their first and second years of the Grundschule Fallersleben primary school in Germany. They were screened by means of a questionnaire completed with the help of their parent/guardian. Children included in the study were 6–8 years of age, had a BMI considered normal, walked to school and had at least 3 months' experience either carrying a backpack or pulling a trolley. Those children who reported current pain in their back, arms or legs were excluded from the study. Each eligible child's parent/guardian read a Study Information Sheet and signed an Informed Consent Form prior to participation. Ethical approval for this study was obtained from the AECC Project Panel.

Thirty-four subjects in total participated in the trial. Children were assigned to either the backpack (n = 19) or trolley group (n = 15) depending on which method they routinely used: a backpack or trolley respectively.

Equipment

A backpack was prepared with sandbags to a total weight of 3 kg (approximately 11% of the mean BW). The same backpack was then used in conjunction with the trolley (Fig. 1).

Postural analysis was carried out using the sonoSens® ultrasound device which assesses body movements using ultrasonic measurement. The device comprises a flat, lightweight unit with a keyboard, display and eight ultrasound transmitters/sensors which are cable-connected to the unit. The unit can be attached to the clothing of the subject making the sonoSens® portable and suitable for posture analysis during walking. Measurements were made via four pairs of miniaturised ultrasound transmitters

Figure 1 The backpack and trolley used as the intervention. The backpack consists of a frame at the front and one at the back. It can be detached from the trolley to be carried on the back. On the other hand, it can be fastened onto the trolley, as seen on the picture, to be pulled behind.

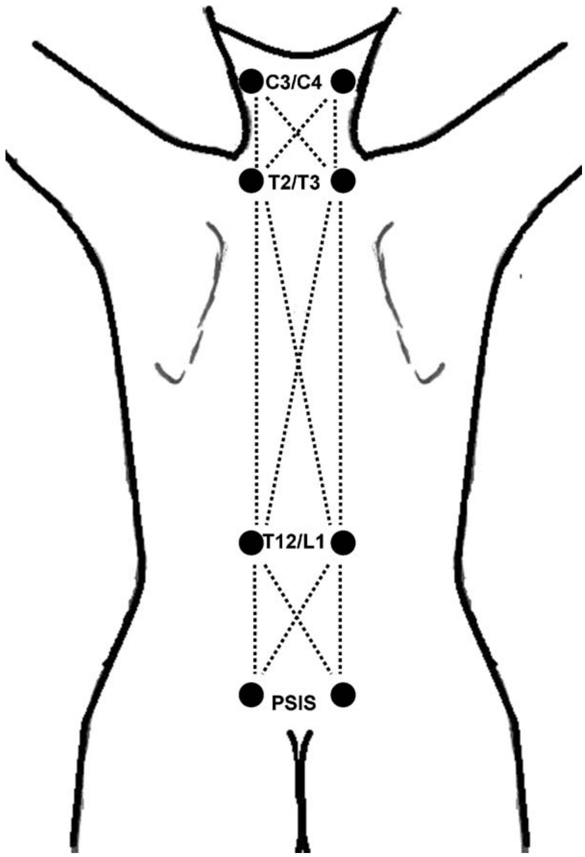

Figure 2 The four pairs of miniaturised ultrasound transmitters and receivers were placed 5 cm left and 5 cm right of the spinous processes at the cervical vertebrae C3/C4, the thoracic vertebrae T2/T3, the thoracic-lumbar junction T12/L1, and medial to the posterior superior iliac spine (PSIS). To prevent the stickers from falling off during the measurement, they were covered with tape (not shown in the picture).

and receivers attached to the skin resulting in 12 measuring channels (see Fig. 2). For each channel, the skin distance between transmitter and receiver is determined by the amount of time that passes between sending and receiving the signal.

Data collection

The design of the experiment is illustrated by Fig. 3. At the beginning of each trial, a set of measurements were made. These were performed in a room within the school building. The child was instructed to stand still for 30 s in a natural but upright stance, their maximum ranges of motion of the whole spine (flexion, extension, lateral flexion to the right and left, rotation to the right and left) were then recorded. Each position was to be maintained for 10 s.

The remaining measurements were recorded during two walks around the school building. The route was chosen with regard to evenness of the terrain and the length of the walk. It was calculated that the route should take approximately 7 min to walk and the subjects were instructed to walk at a constant pace that was not tiring. Each child was accompanied on the walk to ensure the route was the same and data were collected properly.

During the first phase, the subject walked along the route without the intervention (B1 and T1 for the backpack and trolley groups respectively). This task was the same for all subjects irrespective of their allocated group.

The second phase of data collection consisted of the same walk this time with the intervention, either backpack (B2) or trolley (T2) depending on the allocated group. The recording equipment remained in place during the break between phases one and two. On completing phase two, the device was removed.

Posture analysis measures

The outcome measures used for postural analysis were the median sagittal bending index (mSBI, flexion/extension), median frontal bending index (mFBI, lateral flexion) and median torsion index (mTI, rotation). These were measured in degrees and recorded independently for the thoracic and lumbar spine. Measurements were taken from the last 30 s of each walk (6.30—7.00 min) resulting in the four sets of data (B1, T1, B2 and T2). These data were calculated using the program provided by Friendly Sensors AG for sonoSens®.

Statistical analysis

The Kolmogorov—Smirnov test was used to test the data for normality. To analyse the baseline data, B1 was compared with T1 using an unpaired *t*-test. A paired *t*-test was used to analyse whether there is an effect on posture when carrying a backpack (comparing B1 with B2) or pulling a trolley (comparing T1 with T2). To analyse the differences in posture during carrying a backpack and pulling a trolley, B2 was compared to T2 using a two-tailed, unpaired *t*-test. All statistical analyses were performed with Microsoft Office Excel 2003® and SPSS 16.0 for Windows®.

Results

Population

The 34 subjects were all between the age of 6 and 8 (7 ± 1 years). Subjects were 1.3 m (± 0.05) tall and had a mean BW of 26.53 kg (± 3.06). Accordingly, the

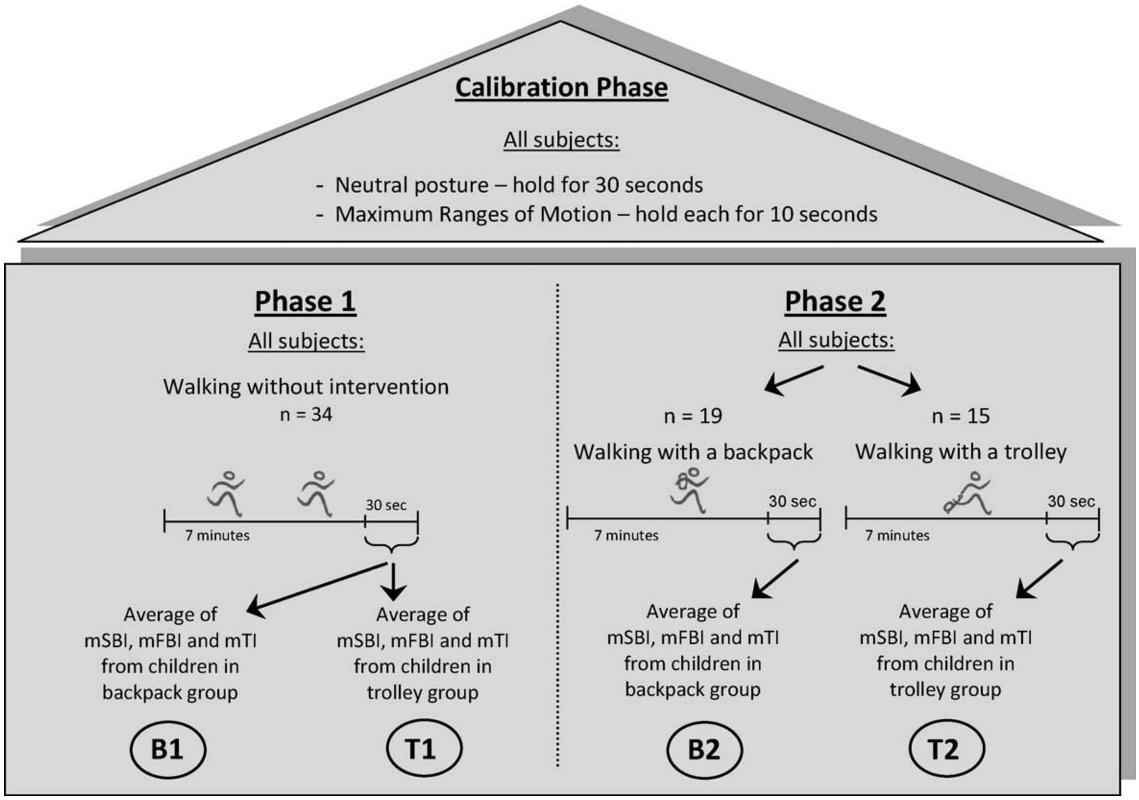

Figure 3 Schematic diagram of the experimental design showing each stage where measurements were taken. Postural measurements consisted of mSBI (flexion/extension), mFBI (lateral flexion) and mTI (rotation) in degrees for every child. B1 and T1 were the initial measurements taken without intervention for the backpack group and trolley group respectively while B2 and T2 are the measurements with the backpack and trolley respectively.

mean BMI of all subjects was 15.84 ($\pm$1.74). There were no significant differences ($p > 0.05$) between the two groups based on these characteristics. The backpack group consisted of 12 male and 7 female subjects compared to 15 females in the trolley group. All data were normally distributed.

Comparison of postures

As can be seen from Table 1, there were no significant differences in postural measurements ($p > 0.05$) between the groups at baseline (B1–T1). Fig. 4(a–f) shows all mean deviations of posture from neutral in degrees.

Within group differences

Comparing walking with and without a backpack (B1–B2), all differences in posture were statistically significant ($p \leq 0.05$) except rotation (mTI) of the thoracic and lumbar spine. However the difference in lateral flexion (mFBI) of the thoracic spine was approaching significance (Fig. 4b).

The effects of walking with a trolley (T1–T2) show statistically significant differences in flexion/extension (mSBI), lateral flexion (mFBI) and rotation (mTI) of the thoracic spine (Fig. 4a–c), as well as a difference in rotation (mTI) of the lumbar spine (Fig. 4f). Only flexion/extension (mSBI) and lateral flexion (mFBI) of the lumbar spine were not statistically significant.

Between group differences

As can be seen from Fig. 4, the backpack group exhibited significantly greater extension of the thoracic spine (Fig. 4a) while the trolley group showed a higher degree of rotation in this area (Fig. 4c). The trolley group also had significantly more rotation in the lumbar spine (mTI, Fig. 4f) while the backpack group were characterised by significantly more lateral flexion (mFBI, Fig. 4d). However, the differences in thoracic lateral flexion (mFBI) and lumbar flexion (mSBI) were not statistically significant.

Discussion

Walking with a backpack

Compared to walking without a backpack, there was an increase in thoracic extension and right lateral

Table 1 Difference (in°), *p*-value and 95% CI of walking without a backpack and without trolley, walking with a backpack and walking with a trolley compared between each other.

		Tx			Lx		
		Difference	*p* value	95% CI	Difference	*p* value	95% CI
B1–T1	mSBI	0.31	0.558	−0.75 to 1.37	0.97	0.654	−3.4 to 5.34
	mFBI	−0.95	0.325	−2.89 to 0.99	1.65	0.338	−1.80 to 5.09
	mTI	0.12	0.867	−1.29 to 1.52	1.06	0.492	−2.05 to 4.18
B1–B2	mSBI	3.91*	< 0.001	3.35 to 4.46	2.2*	0.023	0.34 to 4.06
	mFBI	−1.14	0.052	−2.3 to 0.01	−2.29*	< 0.001	−3.41 to −1.18
	mTI	−0.55	0.187	−1.4 to 0.29	−0.14	0.845	−1.65 to 1.36
T1–T2	mSBI	−0.55	0.001	0.72 to 2.08	−0.15	0.629	−0.82 to 0.51
	mFBI	−0.55	0.001	−1.91 to −0.57	0.07	0.848	−0.66 to 0.8
	mTI	−3.09*	< 0.001	−3.85 to −2.32	3.57*	< 0.001	2.58 to 4.55
B2–T2	mSBI	−2.2*	<0.001	−3.28 to −1.11	−1.38	0.595	−6.63 to 3.86
	mFBI	−1.05	0.366	−3.38 to 1.28	4.01*	0.026	0.51 to 7.50
	mTI	−2.42*	0.003	−3.95 to −0.88	4.77*	0.005	1.55 to 8

A positive value indicates either more, or a movement towards, flexion, right lateral flexion or right rotation. More, or a movement towards, extension, left lateral flexion, and left rotation are represented by negative values. The differences are presented in degrees.

Statistically significant results are highlighted by *. Tx = Thoracic Spine, Lx = Lumbar Spine, B1 = Walking without a backpack, T1 = Walking without a trolley, B2 = Walking with a backpack, T2 = Walking with a trolley, mSBI = median sagittal bending index, mFBI = median frontal bending index, mTI = median torsion index.

flexion of the lumbar spine along with a decrease in lumbar flexion. These results can be interpreted in a similar way to that of Negrini and Negrini[8] for curvature of the spine. They found that a symmetrical load induced symmetrical changes in posture in the sagittal plane, with forward inclination of the trunk but a reduction of the lumbar lordosis and thoracic kyphosis. Negrini and Negrini[8] interpreted these findings as a forward flexion of the whole trunk and a simultaneous elongation of the spine. In their study the lumbar spine was flexed forward resulting in a reduction of lumbar lordosis. The thoracic spine extended backwards which again can be seen as a flattening of the kyphosis and therefore the whole spine would be elongated.

In the current study, the whole trunk was not in forward flexion. Although it has been shown that this is necessary to counterbalance loads on the back,[1] 6.04° thoracic extension and 4.16° lumbar flexion would result in a more neutral or a slight overall extension of the trunk. Apart from the findings of Orloff and Rapp,[9] the results of this trial are in contrast to the recent findings by other researchers described earlier.[2,10–13] One possible explanation is that the difference between lumbar flexion and thoracic extension causes sufficient forward lean to counterbalance the force. Another theory might be that the trunk forward lean is coming from a pelvic tilt and not from the spine.[14] Although pelvic tilt was not measured in the current study, it has not been ruled out in previous investigations.

Walking with a trolley

The trolley group was characterised by a significant increase in extension, right lateral flexion and right rotation in the thoracic spine as well as an increase in left rotation in the lumbar spine compared to walking without a trolley. This supports previous theories regarding the effects of pulling on gait. In particular, the current results show right rotation of the thoracic spine whereas the lumbar spine is rotated to the left. All of the children pulled the trolley with their right hand. This action resulted in pulling back of the right shoulder, which in turn may cause the thoracic spine to follow this movement in order to decrease stresses on the shoulder. However to maintain forward movement the lumbar spine would rotate in the opposite direction resulting in an overall neutral alignment of the body.

Spinal rotation is an essential feature for an efficient bipedal gait, but beyond the extent of its normal range of motion, it is a destabilizing motion in an inherently unstable structure.[15] In addition, rotational movements are a well-known risk factor for the development of low back pain.[16] On the other hand, Kumar et al.[17] stated that a range of 10–15° of axial rotation towards one side of the sagittal axis requires very little muscle effort. The rotation while walking with a trolley was clearly under this range, this suggests that stress in the spinal connective tissues might be low. However, with increasing loads on the trolley, the rotation component might also increase thus leading to

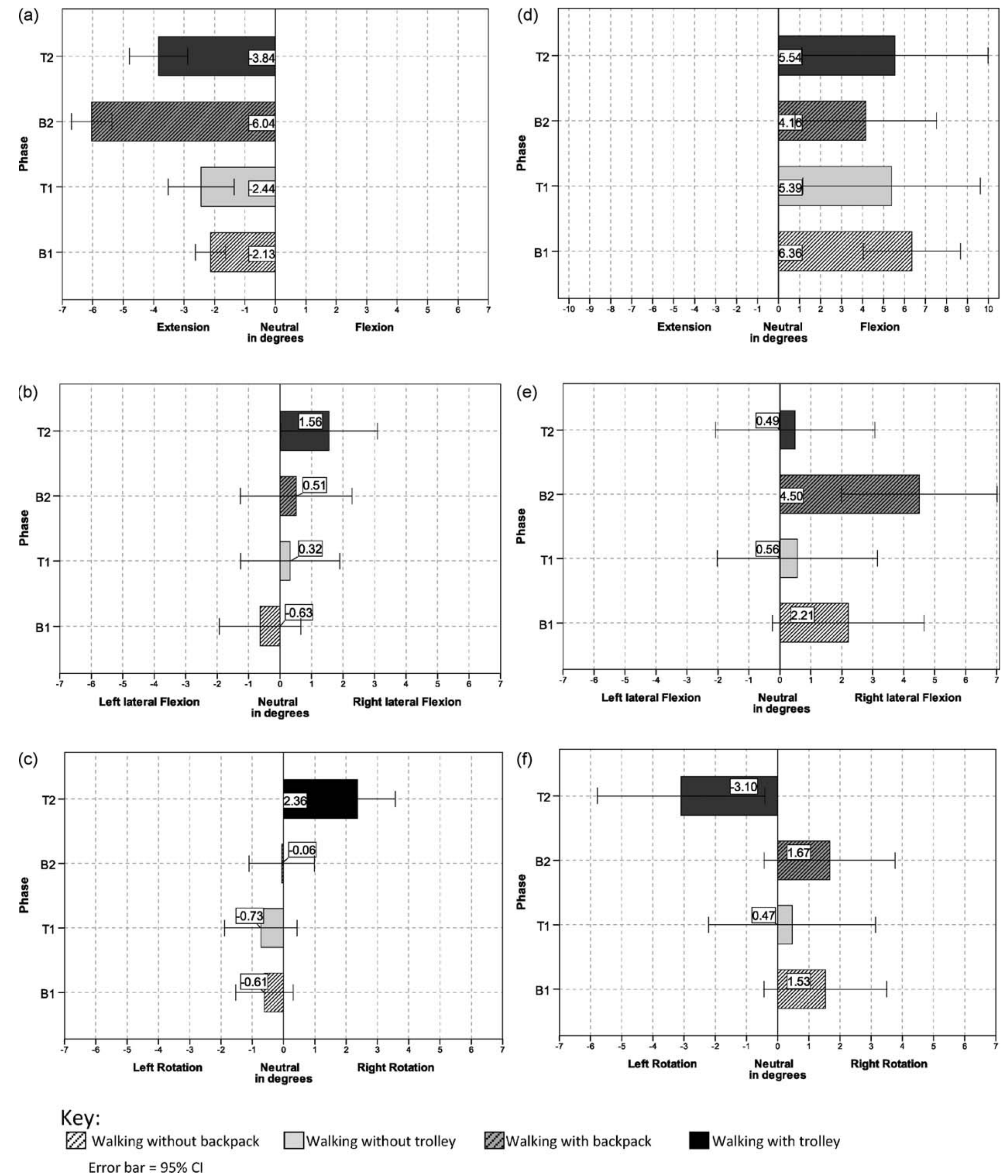

Figure 4 Graphs show a comparison of Flexion/Extension, Lateral Flexion and Rotation in the thoracic spine (a—c) and lumbar spine (d—f) respectively for unburdened walking (B1, T1) and walking with a backpack (B2) or trolley (T2). Bars represent mean values (degrees) and error bars are 95% CI.

increasing stresses on the spine and surrounding soft tissue.

Kumar and Narayan[18] found that torque production capacity is dependent on the body's posture: capacity declined with increasing rotation but increased again in combination with flexion. They also suggested that it requires more muscle effort (thus tissue stress) to generate less torque when asymmetry increases thus weakening the system and enhancing the chances of injury. These findings are very important as the subjects in the current study also have asymmetrical posture.

Therefore, the stress on the tissues seems to be due to additional deviations from neutral rather than rotation. However, Kumar and Narayan[18] assumed a flexed posture of the whole spine while it is only the lumbar spine that is flexed in these children.

Comparison of walking with a backpack and a trolley

Comparison of the backpack and trolley groups showed that the backpack group exhibited a significantly greater degree of thoracic extension and right lateral flexion in the lumbar spine. In contrast, the trolley group had significantly more rotation in both the thoracic (right) and lumbar (left) regions.

Increased forces on lumbar discs are potentially important for both groups; however, due to the slightly greater lumbar flexion, this may be even more so for the trolley group. Furthermore, the asymmetric posture of the trolley group could increase the stresses on soft tissue. However, as has been shown by Carvalho and Rodracki,[16] spinal rotation also increases with backpacks of 20% BW. Since, in reality, it is not uncommon for children to carry such loads and the resulting difference between the postures of walking with a backpack versus trolley may be reduced.

Limitations of the study

The results of this study are only relevant if weight limits (10—15% BW) and aspects of fatigue are kept within the normal limits. As the weight of backpacks increases or fatigue comes into play, the postures change accordingly and the advantage over the trolley may not be as clear. Additionally, long term effects of both transport strategies were not studied and might influence the results.

As children develop, great changes occur in their anatomy and posture. The children in this study were aged 6—8 years which limits the applicability of the existing research for comparison as most studies have been conducted with children of different age groups.

The validity and reliability of the system used in the current study (sonoSens®) have been tested for gait analysis studies in adults[19,20]; however, no other studies have been conducted using children.

Conclusion

The present study identified small but significant changes in vertebral column angulations in all planes of movement during walking with a backpack and trolley compared to normal walking. There was no obvious flexion of the trunk in general during walking with the intervention, but rather a more asymmetric posture characterised by flexion of the lumbar spine, extension of the thoracic spine and lateral flexion components. The trolley group in particular were characterised by rotation of the trunk. Since up to two-thirds of back injuries have been associated with trunk rotation,[18] it could be assumed that posture associated with pulling a trolley has more risky components to it than carrying a backpack, within normal weight limits. Therefore, based on the results of this study, it appears to be better to pay attention to the appropriate weight of the backpack and carrying guidelines rather than utilising trolleys.

Contributors

JS conceived the idea for the study. JS and SD contributed to the final protocol and design of the study. JS is responsible for the research. JS planned, organized and did the data collection, as well as data analysis. JS and SD wrote the first draft of the manuscript. JS coordinated funding of the project. All authors edited and approved the final version of the manuscript.

Conflict of interest statement

The authors have no conflict of interest.

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