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Head load carriage and pregnancy in West Africa

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abstract

Background: The postures of the trunk and of the head relative to the trunk adopted during the specific task of head load carriage were measured for a group of pregnant women and a control group of non-pregnant women because this activity was identified as a risk factor for back pain during pregnancy.

Methods: The postural data of the trunk and of the head relative to the trunk were collected using two inclinometer devices and an electrogoniometer, respectively.

Findings: During walking, the load on the head caused significantly larger upper trunk extension and smaller flexion of the head relative to the trunk. The amplitude of motion of the upper trunk and of the head relative to the trunk, as measured by the standard deviation of walking angles, was found to decrease as a result of carrying a load on the head and compensated by increased motion at the sacrum. Pregnant women showed larger upper trunk movements than their counterpart in the frontal and sagittal planes during the unloaded walking trials.

Interpretation: These posture modifications were believed to be adopted by the subjects to provide better stability for the load during walking. These prolonged postural strains caused by the trunk being displaced from its normal position can lead to muscle fatigue and ultimately to musculoskeletal injuries. The larger movements of the upper trunk for the pregnant women were hypothesized to be due to the enlarged abdomen of pregnant women as it creates a larger moment about L5/S1 and increases instability.

1. Introduction

Back pain is a common problem among pregnant women from all ethnicities with a high prevalence ranging from 48 to 56% depending on the study (Fast et al., 1987; MacEvilly and Buggy, 1996; Mantle et al., 1977; Ostgaard et al., 1991). This universal back pain predicament can significantly decrease the quality of life of pregnant women and interfere with their normal daily activities and work (Ostgaard et al., 1991). Intensive farm work and heavy weight lifting were found to be factors that increase the severity of back pain (Worku, 2003). In some parts of the world, women commonly participate in daily agricultural and commercial activities that require strenuous physical work involving heavy loads carried on the head and back. More precisely, African women are known to frequently balance on their heads heavy loads corresponding to as high as 70% of their body weight (Heglund et al., 1995). The repetitive trunk flexion to lift and lower the load carried on the head also represents a physically taxing motion. This demanding task combined with pregnancy can result in back pain that may persist after delivery in some cases (Poole, 1998; Worku, 2003). In this study, the authors decided to target the specific activity of head load carriage as a potential risk factor for back pain, for pregnant women in West Africa due to its physical nature and the stress borne by the vertebral column.

Up to now, the literature has mainly documented the physiological aspects of head load carriage (Heglund et al., 1995; Lloyd et al., 2010; Maloiy et al., 1986) as well as the degenerative changes of the neck vertebrae as a result of this practice (Echarri and Forriol, 2005; Jager et al., 1997), but little is known about the postures adopted during this task. However, it has been shown that the postures assumed during a work task are an important determinant of musculoskeletal injuries (Vieira and Kumar, 2004). Consequently, there is a lack of knowledge on the trunk postures and biomechanics of this particular form of load carriage that needs to be filled to allow for possible recommendations. Therefore, the objectives of this study were to 1) determine how the walking trunk postures of pregnant women are affected by a load carried on the head, 2) compare these walking postures with a control group of non-pregnant women, 3) determine how the movement of the head with respect to the trunk is affected by head load carriage, and 4) compare these movements of the head with respect to the trunk between the pregnant and control subject groups.

This study is intended as an exploratory study to make a first contribution to the literature by identifying the stressful postures adopted during head load carriage. Prenatal courses are slowly emerging in Benin, and their benefits have been shown by Lawani et al. (2003). They would represent a good commencement strategy to teach pregnant women on ways to work with their changing

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bodies. The observations and findings of this study can help in the development of preventative concepts to decrease the occurrence of back pain.

2. Methods

2.1. Participants

Twenty-six pregnant women (age 26 SD 5 years) and a control group of 25 non-pregnant women (age 26 SD 7 years) with past or present experience of head load carriage were recruited in Porto-Novo, Benin, for this study. Women unable to lift and carry a mass corresponding to approximately 20% of their body mass were excluded from this study. Pregnant subjects were recruited at a community maternity center while non-pregnant subjects were recruited through local contacts to match the pregnant women sample in age and height. Mean height and mass for the non-pregnant women were 159 cm (SD 6) and 57 kg (SD 11), respectively, while the mean height and mass for the pregnant subjects were 159 cm (SD 6) and 63 kg (SD 15), respectively. The pregnant subjects were 25 weeks (SD 9) into their pregnancy on average. The study protocol was approved by the Queen's University Research Ethics Board and by the Institut National de la Jeunesse, de l'Éducation Physique et du Sport (INJEPS) Ethics Board in Benin. Informed consent was obtained from all subjects.

2.2. Data acquisition

2.2.1. Trunk

Trunk postural data during the specific task of carrying loads on the head were collected using two Virtual Corset™ (VC) (MicroStrain, Williston, VT, USA). This device is an inclinometer system combined with a miniature datalogger enclosed in a light pager-sized plastic case. It is battery-powered, wireless, and composed of two bi-axial accelerometers positioned orthogonally. Using an algorithm developed by the manufacturer, the accelerations measured by the accelerometers are transformed into angle data to monitor trunk inclination with respect to an individual's upright position or the line of gravity in two directions (flexion and lateral bending).

Participants were instrumented with two devices at the C7 and sacrum (S1) levels to obtain the trunk inclination angles of the upper trunk and pelvis, respectively, relative to the subject's upright neutral posture. The VC monitoring the upper trunk postures was placed as close as possible to the bony landmark of C7 on the back of the subject in a custom pocket secured to the trunk using elastic Velcro straps around the torso and shoulders, while the VC at the sacrum was attached to a Velcro belt fastened around the waist (Fig. 1A). The VCs were also aligned with the body anatomical axis. Data were sampled at a rate of 7.5 Hz and were stored on the built-in non-volatile memory of the device until the completion of all trials for each subject at which point the data were downloaded to a computer via the Windows-based Virtual Corset control software (VC-323, Microstrain Inc., Williston, VT, USA) for further analysis.

2.2.2. Head with respect to the trunk

The movement of the head with respect to the trunk in the sagittal plane was measured using an electrogoniometer (model M180, Penny and Giles Inc., Blackwood, UK). The top end-block of the electrogoniometer was attached to the head using one or two elastic head bands, while the other end-block was fixed to the trunk with medical tape (Fig. 1B). The bottom end-block of the electrogoniometer was taped to the back of the subjects in a manner such that the spring connecting the two blocks was fully extended when the heads of the subjects were held in their neutral upright postures. Data were sampled at 100 Hz and acquired onto a laptop using a customized computer program developed within Labview 8.0 (National Instruments, Austin, TX, USA) and stored on a computer for further processing.

Fig. 1. A) The two VCs worn by a pregnant woman at C7 and sacrum levels. The VC at C7 is secured in a small custom pocket attached to the subject around the torso and shoulders. The VC at sacrum is attached to a belt fastened around the waist. B) Zoomed view of picture (A) to show the electrogoniometer attached by the headbands and a close view of the VC at C7.

2.3. Procedure

In order to evaluate the effect of head load carriage on the walking trunk postures and positions of the head with respect to the trunk, the subjects were asked to walk under two loading conditions. The first task consisted of walking without any load on the head, while the second task included the lifting, carrying and lowering of a load. The mass of the load was chosen to correspond to approximately 20% of each subject's body mass based on preliminary field data collected in Benin. These preliminary data showed that the average load carried on the head by pregnant and non-pregnant women corresponded to 28% of their body mass. Typical loads carried on the head were mocked by a bag of sand to facilitate the adjustment of its mass for different subjects. Field observations revealed that loads were typically not placed directly on the head but rather on a circular metal or wooden tray. It was also noticed that loads were lifted from a raised surface such as a small stool as opposed to being lifted from the ground level. These lifting and head load carriage conditions observed in the field were replicated in the laboratory by placing the bag of sand on a circular metal tray which was in turn placed on a plastic stool approximately 45 cm tall. Data for this study were collected in a small laboratory set up at the INJEPS.

Prior to data collection, each participant was instructed to stand in their most upright trunk and head postures to set the zero (reference) position for the two VCs and the electrogoniometer. The walking trajectory for both loading conditions consisted of a straight walkway of about 3 m followed by a turn and the same 3 m walkway to return to the start location, for a total walking distance of approximately 6 m. Each walking condition, loaded and unloaded, was repeated three times for a total of six trials. The unloaded walking trials were always performed prior to those in the loading condition to facilitate data identification in the continuous stream of data recorded by the VC. Body mass was measured upon arrival of the subject at the data collection site on a bathroom scale and recorded by one of the investigators in kilograms with one decimal to determine the mass of the load to be lifted.

2.4. Data processing

All data were processed using custom programs developed in Matlab R2007B (The Math Works Inc., Nathick, MA, USA).

2.4.1. Trunk

The walking portions of the loaded trials were manually selected and removed from the trial to separate the walking trunk angles from the trunk postures during the pick up and put down of the load phases (Fig. 2). The start and end points of the walking portion of each trial were determined by visual inspection of the flexion–extension angles in the sagittal plane for each VC as the bending motion is more detectable in that plane than in the frontal plane. These points were then applied to the corresponding lateral bending data to obtain the walking portion of each trial. All walking data were normalized to 100 data points to match the length of all six trials.

The data from the three trials for each condition were grouped together and assumed to be only one stream of data in order to obtain the mean trunk angle and standard deviation of those angles for the two loading conditions for each subject. Finally, the mean trunk walking angle and mean standard deviation of the walking angles for the non-pregnant and pregnant groups were calculated by averaging the data from all subjects in the same subject group.

2.4.2. Head with respect to trunk

The angles were corrected based on a validation equation developed for the electrogoniometer. The data from the electrogoniometer were then processed similarly to those of the VC. No significant difference for the angles between the trials was detected when using a mixed-design analysis of variance (ANOVA) where the between-subject variable was pregnancy and the within-subject variable was the trial number.

2.5. Statistical analysis

Mixed-design ANOVAs were applied to make comparisons between the mean walking trunk angles, mean walking angle of the head with respect to the trunk, and the standard deviation of the walking angles in the loaded and unloaded conditions for the two subject groups. The between-subject variable was pregnancy and the within-subject variable was the loading condition. Significance level was set to 0.05. In the case of interaction between the two variables, t-tests with Holm adjustment were conducted.

All repeated measures ANOVA's were performed with SPSS 15 for Windows (SPSS Corporation, Chicago, IL, USA) statistical software. Descriptive statistics of the two subject groups were also obtained using this software.

3. Results

The mean masses of the loads carried on the head by the non-pregnant and pregnant women were 11.3 SD 2.1 kg and 11.8 SD 2.2 kg, respectively. Complete sets of trunk posture data were successfully measured and processed on 22 non-pregnant subjects and 23 pregnant subjects. One pregnant subject completed only two of the three loaded trials due to fatigue and bodily pain; however her data were still included in the pregnant group. The data from the VC at the sacrum were lost on six participants (3 from each group) due to malfunction of the instrument during data collection. Complete sets of data for the movements of the head with respect to the trunk were successfully collected and processed on 19 non-pregnant and 16 pregnant subjects. Data from the other 16 subjects were discarded due to malfunction of the instrument during data collection or data loss during processing.

The mean flexion–extension (FE) and lateral bending (LB) walking angles of both subject groups under the loaded and unloaded conditions are summarized in Table 1 along with the mean standard deviations (SD) of those walking angles. The mean angle of the head with respect to the trunk and the standard deviation of those angles during the walking trials are also included in Table 1.

The statistical results of the walking angles are shown in Table 2. The effect size of the significant results was evaluated using the partial

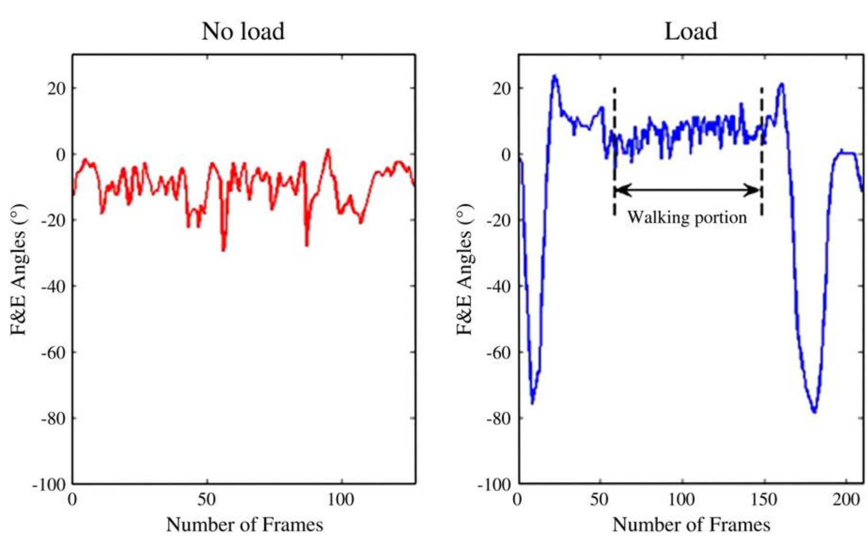

Fig. 2. Example of angle data measured by the VC for non-pregnant subject #1 for one unloaded and one loaded trial. The walking portion section was defined manually by inspection and separated from the other data to compare to the unloaded walking angles. The large flexion angles at the start and end of the loaded trial represent the lifting and lowering of the load motions, respectively.

Table 1
Mean walking angles with respect to the subjects' upright position in flexion–extension and lateral bending and mean SD of these angles in the loaded and unloaded conditions for non-pregnant and pregnant subjects. Negative angles correspond to trunk flexion while positive angles represent trunk extension. Left lateral bending is associated with positive angles and right lateral bending with negative angles. Positive angles for the head movement represent extension of the head relative to the trunk and negative angles correspond to flexion.

	Flexion–extension				Lateral Bending			
	Non-pregnant		Pregnant		Non-pregnant		Pregnant	
	No load	Load	No load	Load	No load	Load	No load	Load
Mean angle C7 (Nnp = 25, Np = 26)	−1.3° (SD 3.4°)	10.4° (SD 6.2°)	−4.1° (SD 6.0°)	8.5° (SD 7.9°)	3.2° (SD 3.0°)	5.5° (SD 4.4°)	4.4° (SD 4.1°)	6.0° (SD 4.5°)
Mean SD at C7 (Nnp = 25, Np = 26)	3.9° (SD 1.1°)	3.5° (SD 0.8°)	5.2° (SD 1.3°)	3.7° (SD 1.0°)	5.5° (SD 1.0°)	4.1° (SD 0.6°)	6.4° (SD 1.7°)	4.7° (SD 1.2°)
Mean angle at sacrum (Nnp = 22, Np = 23)	−0.5° (SD 3.6°)	−0.3° (SD 4.3°)	−1.1° (SD 2.8°)	−0.9° (SD 4.4°)	1.6° (SD 1.8°)	1.2° (SD 2.0°)	1.2° (SD 2.7°)	0.8° (SD 3.0°)
Mean SD at sacrum (Nnp = 22, Np = 23)	5.5° (SD 1.1°)	6.7° (SD 1.3°)	5.1° (SD 1.0°)	6.2° (SD 1.0°)	4.8° (SD 0.9°)	5.2° (SD 1.1°)	4.8° (SD 0.9°)	5.1° (SD 1.0°)
Mean angle of head relative to trunk (Nnp = 19, Np = 16)	−5.4° (SD 10.6°)	0.2° (SD 13.4°)	−4.0° (SD 10.2°)	−1.4° (SD 7.2°)	–	–	–	–
Mean SD of head relative to trunk (Nnp = 19, Np = 16)	9.9° (SD 3.4°)	4.6° (SD 1.1°)	10.1° (SD 3.4°)	5.1° (SD 1.5°)	–	–	–	–

eta squared (η_p^2). All effect size indices but one had values above 0.14 and considered as large (Kinnear and Gray, 2008). The effect size for the main effect of pregnancy for the SD of LB angles at C7 was small as the partial eta squared value was between 0.01 and 0.06 (Kinear and Gray, 2008).

Loading had a significant effect on all mean walking angles and mean SDs of the walking angles with the exception of the mean FE walking angles measured at the sacrum (Table 2). Trunk extension at C7 increased in both subject groups when they were walking with a load on the head. Head flexion angles also decreased to an almost neutral position in the loaded condition. Both subject groups also increased their upper trunk tilt towards the left when walking in the loaded condition but decreased that tilt towards the left at the sacrum level. The SD of the upper trunk FE and LB walking angles at C7 significantly decreased with load, while the opposite effect was demonstrated at the sacrum. Pregnancy only had a significant effect on the SD of the FE and LB walking angles measured at C7, showing larger SD values for pregnant women. Due to the interaction between pregnancy and loading for the SD of FE angles at C7, four t-tests were performed to determine the effect of these independent variables. These four t-tests were: 1) pregnant unloaded vs pregnant loaded; 2) non-pregnant unloaded vs pregnant unloaded; 3) non-pregnant unloaded vs non-pregnant loaded; and 4) non-pregnant loaded vs pregnant loaded. The level of significance of these t-tests was adjusted using the Holm criteria. Load significantly decreased the SD values of the upper trunk angles during walking for the pregnant subjects (t-test 1, P b 0.001). Non-pregnant subjects only showed a marginally significant difference for the SD values between unloaded and loaded conditions when the α-level was adjusted according to Holm criteria (t-test 3, P = 0.1667). Pregnant subjects showed significantly larger SD values than the control group in the unloaded condition (t-test 2, P b 0.001), but the two groups were not significantly different in the loaded condition (t-test 4, P = 0.5140).

Table 2
Mixed-design ANOVA results between the pregnant and non-pregnant women for the mean flexion–extension and lateral bending walking angles and SD of those walking angles at C7, sacrum and head relative to the trunk during loaded and unloaded conditions.

Variable	Main effect of pregnancy		Main effect of loading		Interaction	
	F statistic	P-value	F statistic	P-value	F statistic	P-value
FE at C7	2.195	0.145	438.261	0.000[a]	0.622	0.434
SD FE at C7	8.080	0.007[b]	34.586	0.000[a]	10.447	0.002[a]
LB at C7	0.670	0.417	16.311	0.000[a]	0.456	0.503
SD LB at C7	5.988	0.018[b]	147.194	0.000[a]	1.713	0.197
FE at sacrum	0.276	0.602	0.675	0.416	0.028	0.868
SD FE at sacrum	2.366	0.131	127.545	0.000[a]	0.473	0.495
LB at sacrum	0.377	0.542	7.580	0.009[b]	0.001	0.981
SD LB at sacrum	0.082	0.776	10.421	0.002[b]	0.428	0.517
Head angle relative to trunk	0.001	0.971	7.042	0.012[b]	0.931	0.342
SD head relative to trunk	0.310	0.582	81.599	0.000[a]	0.106	0.747

[a] Indicates significance at the P b 0.001 level.
[b] Indicates significance at the P b 0.05 level.

4. Discussion

The specific purpose of this study was to compare the postures of the trunk and postures of the head relative to the trunk adopted during walking in an unloaded and loaded condition for two female subject groups: pregnant and non-pregnant. The main results were a significant increase in upper trunk extension in the loaded condition accompanied by a significant decrease of the SD of the FE and LB walking angles at C7. This decrease in the SD of walking angles at the upper trunk was compensated by a significant increase of the SD of walking angles at the sacrum.

4.1. Main effect of load

4.1.1. Trunk and head inclination during walking

In accordance with previous observations for a normal population (Syczewska et al., 1999), the results of this study show that the trunk was bent forward during unloaded walking in relation to the standing position. This forward bend of the trunk was observed to be a characteristic phase of gait initiation (Breniere and Do, 1987). It is also believed to minimize the energy consumption during the propulsion phase and help the hip extensors (Syczewska et al., 1999). Conversely, upper trunk extensions as well as smaller flexion angles of the head relative to the trunk were observed during the walking portion of the head load carriage task. It is hypothesized that this increase in trunk extension and decrease in flexion angles of the head with respect to the trunk were performed to shift the center of gravity of the upper body-and-load and head-and-load over their centers of rotation, L5/S1 and C1, respectively, to counteract the flexion moments caused by the load which is located anteriorly to the neck and vertebral column when placed on the head. This compensation mechanism for trunk inclination has been shown for load carriage in backpacks, where forward tilt postures are adopted to counteract the moment created by the load placed on the back (Bobet and Norman, 1984; Hong and Cheung, 2003; Kinoshita, 1985). These changes in trunk and head angles from the normal position can stress the back muscles and ultimately lead to back problems due to the prolonged postural strain on these muscles (Chaffin and Andersson, 1991). Furthermore, heavier loads do not move in synchrony with the trunk (Pierrynowski et al., 1981), thus causing cyclic stress to the back ligaments and muscles (Harman et al., 1992).

The increase in the average lateral tilt towards the left during loaded walking may be explained by the load carriage method employed by the women. Women typically use their dominant arm and hand to help balance the load while walking. All our subjects, with one exception, were right-handed and therefore used their right arm and hand to hold the load. As a result of this practice, the upper trunk is more inclined towards the left during loaded walking. It is also possible that the VC was moved towards the left by the scapula when the arm was raised to hold the load, thus increasing the inclination of the VC at C7 towards the left in the loaded condition. The mean lateral walking angle at the sacrum shifted in the direction opposite to the upper trunk during load walking. The decrease in tilt angle of the sacrum towards the left is assumed to be a compensation mechanism to counterbalance the lateral bend of the upper trunk.

4.1.2. Motion of the trunk and head during walking

The load placed on the head is unstable due to its high placement with respect to the body center of gravity and the lack of attachment to the head. In fact, significantly larger swaying motion of the body in the horizontal plane was observed when static standing of head load carriage method was compared to that of other methods of carriage (Filaire et al., 2001). The instability of the load is further increased during walking because of the moments due to angular accelerations of the upper-body-and-load. In order to avoid dropping of the weight, reduced motion of the head and upper trunk is required to minimize the movements of the load. This phenomenon of reduced upper body motion is illustrated by the decline in the SD of the walking upper trunk angles and movements of the head with respect to the trunk as the movements are contained within a smaller range of angles. The contraction of the core muscles to compensate for the sway of the load and to counterbalance the load requires some amount of static work. This static muscular effort demands considerable energy expenditure and is fatiguing (Soule and Goldman, 1969), and it may possibly lead to musculoskeletal injuries. On the other hand, the SD of the FE and LB angles at the sacrum increased significantly in the loaded condition. This increase in movements at the sacrum during head load carriage is hypothesized to be a compensation mechanism to counteract the lack of motion in the upper trunk and allow for normal motion of the legs.

4.2. Main effect of pregnancy

4.2.1. Trunk and head inclination during walking

The parameters measured in this experiment were similar between the two subject groups. These results are in accordance with those of Foti et al. (2000) who found that the gait and trunk tilt during pregnancy remained remarkably unchanged.

4.2.2. Trunk and head motion during walking

Pregnancy had a significant effect only on the SD of the upper trunk angles in the unloaded condition. Increased instability in the antero-posterior direction was also observed during standing for pregnant women (Jang et al., 2008). In fact, the localized weight of the fetus creates larger moments about the center of rotation of the lower back, L5/S1, thus creating an imbalance of the upper trunk. It is hypothesized that the pregnant women attempted to reposition the center of gravity of the upper trunk, now displaced in the forward direction, back over the center of rotation of the lower back by rotating the trunk backward to maintain balance during walking. Consequently, the significantly higher SD of the upper trunk in the unloaded condition may be explained by the combination of the slight trunk flexion during locomotion (Syczewska et al., 1999) and the attempt to reposition the center of gravity backwards due the enlarged abdomen of pregnant women.

Despite the significant effect of pregnancy on the SD of the upper trunk angles in the unloaded condition, it did not have a significant effect on the upper trunk movements in the loaded conditions. These results suggest that pregnant women reduced their upper trunk motion more from unloaded walking than the non-pregnant group to balance the load on the head in the loaded condition. Consequently, this larger reduction of motion of the upper trunk in the pregnant group would indicate that the core muscular effort provided by the pregnant women in the loaded condition was higher than their counterpart, thus potentially exposing them to a higher risk of back injury.

4.3. Limitations

The VC is an inclinometer that reports inclination angles relative to the line of gravity in static situations (Hansson et al., 2001). However, the presence of dynamic accelerations directly affects the angles outputted by the VC because the acceleration vector can deviate from the line of gravity (Hansson et al., 2001). Angle values must be analyzed with caution as the inclinometric interpretation may not be valid with large accelerations. However, the angles measured by the VC in this study were compared between subject groups and conditions. Dynamic accelerations were assumed to be similar between subjects and conditions and to affect all measurements similarly, thus counteracting their effects on the angles when comparing results. Consequently, the comparisons performed in this study are thought to be valid despite the effects of dynamic accelerations on the angles.

The walking postures from the different trials from the two conditions were combined together as they were assumed to be similar between trials. However, the order of execution of the trials was not randomized as the unloaded condition was always performed first followed by the loading condition. This order was not randomized during data collection to avoid possible confusion in the identification of trials because of the continuous recording of the VC. However, it was assumed that the order had no effect on the measurements and that all trials were similar since subjects were accustomed to the natural task of walking, with or without a load. Randomization would be preferred in future studies where each individual trial can be identified.

There are also some limitations associated with the fixation of the instrumentation onto the subject's body. Medical tape, head bands, and a custom harness secured with adjustable elastic straps were used to attach the electrogoniometer and VC onto the subject's head and trunk, respectively. However, it is possible that the device became slightly displaced during data collection. This displacement of the VC from its reference position particularly increases the errors of the angles reported by the VC because all angles are reported relative to the subject's upright standing posture.

5. Conclusion

This study investigated the head load carriage task as it was identified as a potentially high risk activity for back pain by the authors. The results showed that trunk postures significantly changed during head load carriage with higher upper trunk extension. Reduced motion of the upper trunk and head was also observed in the sagittal and frontal planes to provide better stability for the load balanced on the head. Conversely, motion at the sacrum increased during head load carriage to compensate for the reduced motion of the upper trunk and allow for normal gait. These trunk posture deviations from its normal position can lead to muscle fatigue and ultimately lead to musculoskeletal injuries (Soule and Goldman, 1969). Pregnant women showed larger upper trunk movements than their counterpart in the frontal and sagittal planes during the unloaded walking trials but similar upper trunk motion in the loaded condition. The larger movements in the unloaded condition were hypothesized to be due to the enlarged abdomen of pregnant women that creates a larger moment about L5/S1. The similar upper trunk motions observed between the two groups in the loaded condition suggest that the demand on the trunk musculature was even higher for pregnant women to balance the load on the head.

Conflict of interest statement

There is no conflict of interest associated with the work of this manuscript.

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