Work 47 (2014) 63–72
DOI 10.3233/WOR-131686
IOS Press

Posture analysis of lifting a load for head carriage and comparison between pregnant and non-pregnant women

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Received 27 August 2012
Accepted 25 April 2013

Abstract.
BACKGROUND: In Western Africa, women continue performing heavy physical work that includes carrying loads on their heads during pregnancy. Women may adapt to pregnancy related body changes by modifying their postures to perform such tasks.
OBJECTIVE: The objectives of this biomechanical task analysis study were to 1) determine sagittal plane postures of the trunk and upper extremities at specific events during the task of lifting and lowering a load to be carried on the head, 2) compare postures of pregnant and non-pregnant participants, 3) evaluate risk for musculo-skeletal disorders (MSD) with the rapid entire body assessment (REBA) criteria.
PARTICIPANTS: Twenty-six pregnant (26 $\pm$ 5 years, 159 $\pm$ 9 cm, 63 $\pm$ 15 kg, 25 $\pm$ 9 weeks of pregnancy) and 25 paired non-pregnant retail merchants were recruited in Porto-Novo (Benin).
METHODS: Participants were recorded on video in a laboratory setting while they lifted a tray (20% body weight) from a stool to their head and then put it back down. Trunk inclination and knee, shoulder and elbow flexion angles were determined using Dartfish^{TM} software.
RESULTS: The trunk was bent by more than 80° at pick-up and set-down and knees were moderately flexed, significantly less ($<11^\circ$) for pregnant women, possibly because it was harder to lift the trunk, or for stability. For all postures analysed, the majority of trials were classified as "high" risk or "very high risk" for MSD.
CONCLUSIONS: Future research should investigate prevalence of MSDs in this population to confirm the results of this study.

Keywords: Musculoskeletal disorders, pregnancy, Africa

1. Introduction

Pregnancy induces physiological changes in women's bodies and is often associated with back pain [1]. Back pain in pregnancy has been found to occur in a large proportion of women across many different ethnicities [2–4]. In the most severe cases, back pain can prevent women from completing their normal daily activities [5], and it can persist after pregnancy [6–8]. Heavy physical work, and particularly manual material handling and repeated trunk flexion and/or torsion have been related to low back pain in the general population [9,10] and in pregnant women [5]. However, many women continue to complete their daily physical activities while pregnant. This is the case for pregnant women who do not benefit from social protection and rely on their work to support their families.

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This study specifically investigates merchant women of Benin, Western Africa because, although the relation between heavy physical work and risk of musculo-skeletal injury has been studied in western societies, it has not been studied as well in other parts of the world. In Benin and other Western African countries, retail sales are dominated by women. Merchants carry the goods that they sell on their heads, and some African women have been shown to balance loads of up to 70% of their body weight on their heads [11]. This task requires repeated lifting to raise the load onto the head, and may put them at risk for low back pain and upper extremity injury.

Pregnancy-related body changes such as increased trunk mass, anterior displacement of upper body centre of mass, and increased ligament laxity may affect the way that pregnant women perform lifting tasks. Previous work has shown that increased body mass could not explain all differences in change in L5/S1 loads as pregnancy progresses [12], and it was suggested that posture may account for some of the change.

The objectives of this study were to 1) determine sagittal plane postures of the trunk and upper extremities at specific events during the task of lifting and lowering a load to be carried on the head, 2) compare posture of pregnant and non-pregnant participants, 3) evaluate risk for musculo-skeletal disorders based on the REBA criteria [13].

2. Method of analysis

2.1. Study design

This biomechanical task analysis study required pregnant and non-pregnant women to perform the same lifting task, which was recorded on two perpendicular video cameras. Video analysis software was used to determine joint and segment angles, including the trunk, knee, shoulder, elbow , neck and wrist at four events during the task.

2.1.1. Participants

Twenty-five non-pregnant women (age 26 ± 7 years) and twenty-six pregnant women (age 26 ± 5 years) with experience in overhead carriage were recruited in Porto-Novo, Benin, for this study [14]. The average height and mass for the pregnant group was 159 cm (± 9) and 66.4 kg (± 15.5). The average height and mass for the non-pregnant group was 159 cm (± 6) and 59.8 kg (± 11.1), respectively. The pregnant participants were an average of 25 weeks (± 9) into their pregnancies. Inclusion criteria were i) to be pregnant (study group) or in child-bearing years (control group), ii) to be a stationary or ambulatory retail merchant, iii) to be currently active and practicing head load carriage. This study was approved by Queen's University Research Ethics Board, Canada, and by the Institut de la Jeunesse, de l'Education Physique et Sportive (INJEPS) Ethics Board in Benin. Informed consent was obtained from all participants [14].

2.1.2. Task

As part of a companion study [15], the participants walked 3 m straight ahead from the starting area, turned around, and walked back to the starting area. This was repeated three times.

Next the participants were required to perform the task with a load. They had to raise a load that corresponded to 20% of their own body weight from a stool at a height of 45 cm off the ground, and onto their head (Fig. 1). It is to be noted that many merchants use a stool to put their goods to avoid lifting the load from the floor. Once they placed the load on their head, the participants walked 3 m in a straight line, turned around, and walked 3 m back to the starting area. The participants then lowered the load and set it back onto the stool that was handled by an assistant during the testing. This was also completed three times.

2.1.3. Data collection

All data were collected at the Institut National de la Jeunesse, de l'Éducation Physique et du Sport (INJEPS) in Porto Novo during the months of June and July 2009.

Data collection was performed with two digital cameras (Sony HandyCam DCR-SR82) fixed on tripods at 1 m above the ground. Both cameras were placed 5 m from the starting area to record the picking up and setting down motions in the sagittal and frontal planes, respectively. The videos from this camera were used for the REBA analysis to rate upper extremities' postures. For the analysis of joint angles, it was assumed that the motion was symmetrical and occurred in the sagittal plane (see Discussion).

2.1.4. Data processing

Video analysis software (Dartfish^{TM} Prosuite, version 4.0.9.0, Lausanne, Switzerland) was used to synchronize the videos from the two cameras and to measure joint angles. Joint angles were measured at four critical events during the lifting and lowering parts of

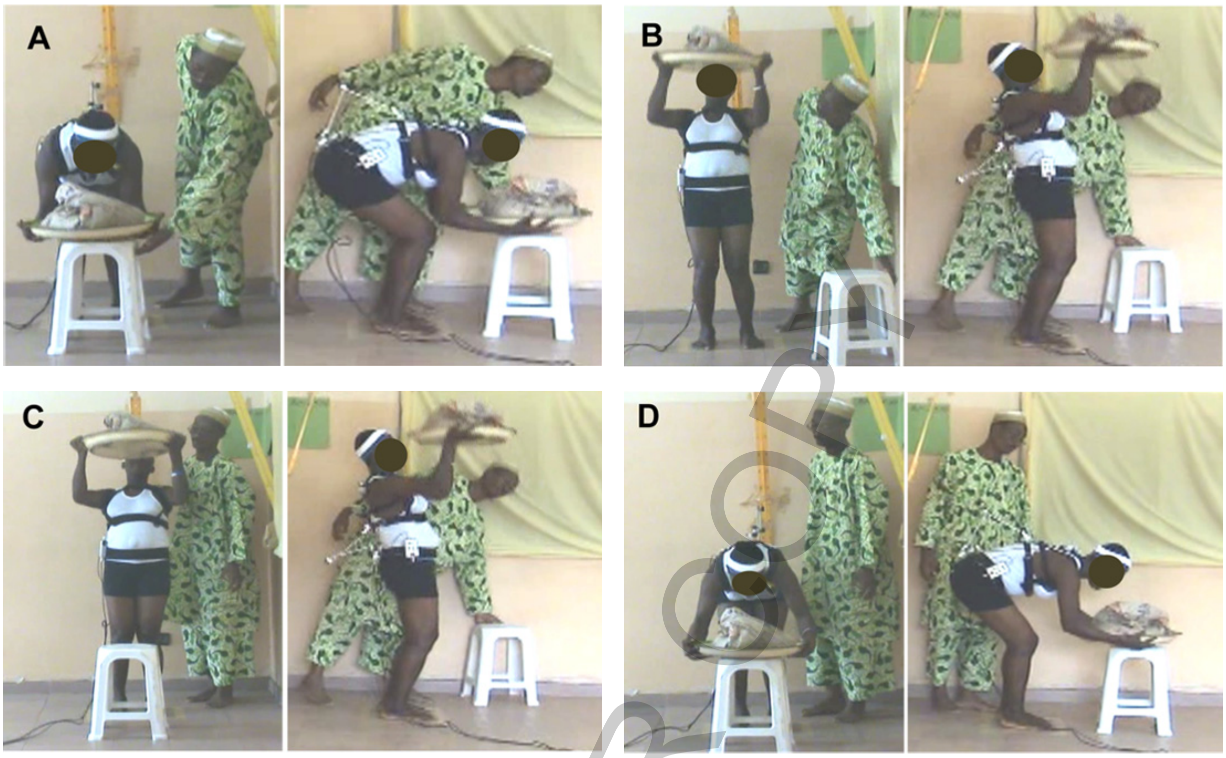

Fig. 1. Front and side views of the four events selected from the videos for analysis. A) Pick-up, B) 1st extension, C) 2nd extension, D) Set-down. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/WOR-131686)

the task that were selected based on trunk flexion and trunk extension (the carrying part of the task was not studied here) as follows (Fig. 1):

1) Pick up the load from the stool (pick-up),
2) Initial trunk extension when placing the load on the head (1st extension),
3) Trunk extension when removing load from the head just prior to setting it down onto the stool (2nd extension),
4) Setting the load down onto the stool (set-down).

Frame by frame control was used in Dartfish™ to ensure that maximum trunk flexion and extension were being analysed. Often participants would hold a constant trunk flexion or extension angle for a couple of frames. In the event of constant trunk flexion/extension, the frame where the participant also exhibited maximum arm flexion was selected as the frame to be analysed.

Joint and segment angle measurements included flexion/extension of the knee, shoulder, elbow and wrist, as well as trunk and neck angles with vertical. The definition of these angles outlined by the rapid entire body assessment (REBA) method was used [13], and is represented in Fig. 2.

In order to evaluate the repeatability of joint angle measurements, each measurement was digitized three times for pick-up and 1st extension events for the first trial of 10 non-pregnant participants. Only participants with uneven study codes were included for repeatability assessment. The same trials were digitized by a second operator to evaluate inter-rater repeatability, but for all other data included in this study, the videos were digitized by the same assistant. Assistants received training in using Dartfish™ software and angle/event definitions and they performed practice tests before processing the data.

2.1.5. REBA risk analysis

REBA [13] was used to determine a risk score associated with posture. REBA scores each joint angle measurement according to the degree of flexion or extension of the segments, taking into account additional factors such as asymmetry, load, coupling and action. These scores are used to determine a final risk factor from the REBA method.

Joint angle measurements from Dartfish™ were used to determine the scores for flexion-extension, except for the wrist and neck. Wrist and neck postures

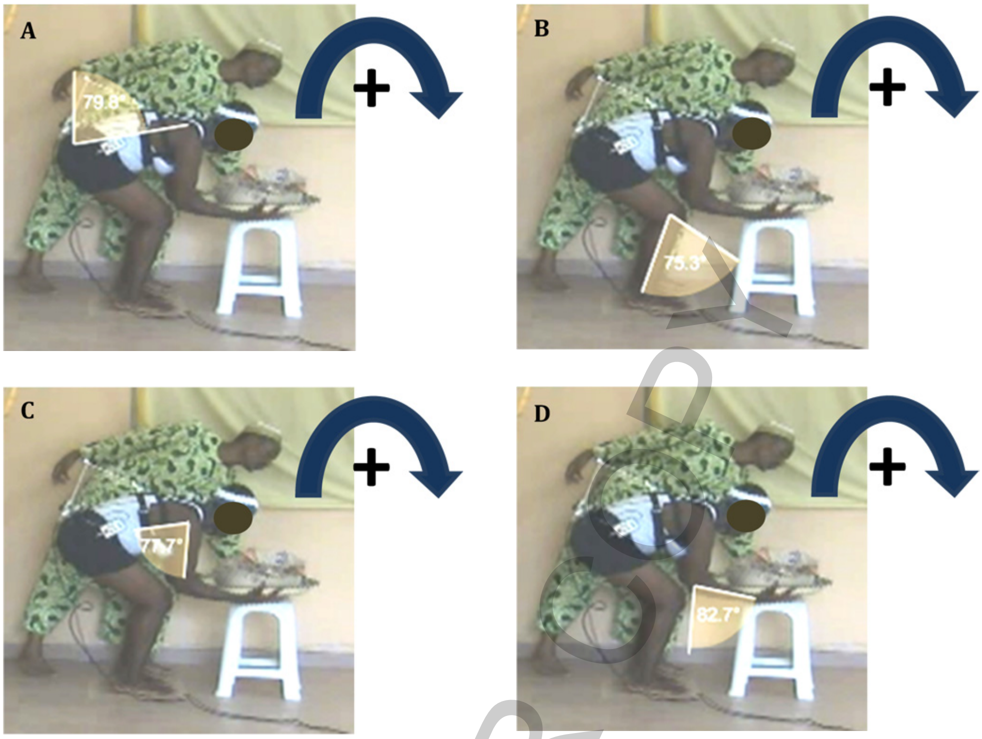

Fig. 2. Definition of the four angles digitized from the video pictures at pick-up. A) Trunk inclination with respect to vertical. The trunk is defined as one segment from L5 to C7. B) Knee flexion, measured from the longitudinal axis of the shank to the extension of the longitudinal axis of the femur. The shank is defined as the segment between the ankle and knee joints, the femur is defined as the segment between the knee and hip joints. C) Arm flexion, measured from mid-section of the body (parallel to trunk segment in A) to arm. The arm is defined as the segment between the acromion and lateral epicondyle of the humerus. D) Forearm flexion, measured from the extension of longitudinal axis of the arm to the longitudinal axis of the forearm. The forearm is the segment between the lateral epicondyle of the humerus and the wrist joint. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/WOR-131686)

were determined from direct observation of the videos, as REBA is a method for visual observation and only requires postures to be classified into broad categories. For the arms, the score was augmented by 1 because the arms were in abduction in accordance to the REBA scoring protocol. The load score was set to 2 for participants who lifted more than 10 kg and to 1 for the others who lifted between 5 and 10 kg. The coupling score was set to 0 for all as the tray was relatively easy to grasp and hold. Finally, the activity score was set to 1 for all because of the rapid change in posture in all events (third case for adding an activity score of 1 in the REBA protocol [13]).

2.2. *Data analysis*

2.2.1. *Repeatability*

Intra-class correlation coefficients (ICC) were calculated to evaluate the repeatability of the digitizing using IBM SPSS Statistics 20. The standard deviations between the three digitized values of the same picture and their average over participants were also computed in Excel 2007.

2.2.2. *Comparison between trials*

A comparison between trials was performed to determine whether the task was repeatable or there was an effect of repetition.

For a given set of joint angles that included all three trials for each participant for a given event, analysis of variance (ANOVA) was used to test whether there was a significant difference between joint angle measurements across all trials. ANOVA was performed in Excel 2007, using the *ANOVA*: Single Factor with replication with a level of significance $\alpha = 0.05$.

2.2.3. *Comparison between pregnant and non-pregnant women*

As no significant effect for trial was found in the previous tests, the values of the three trials for each angle were averaged and the mean was used for the comparison between groups using unpaired t–tests. These tests were performed in Excel 2007 with a level of significance of $\alpha = 0.05$.

2.2.4. Additional tests with data from early stages of pregnancy excluded

For all the above analyses, all pregnant participants were included in the testing. As the group of pregnant women included women from early pregnancy to 40 weeks, there was concern that the participants in early pregnancy had not yet experienced much body change, more specifically in mass gain, and may not have changed their lifting style. Therefore, a second set of tests were conducted for all comparisons between the two groups in which the participants from the pregnant group who were not more than four (4) month pregnant were excluded. The results from these tests were inspected to see whether any differed in significance from those of the tests that included all pregnant women.

3. Results

During the analysis, six participants were excluded because they did not have complete data sets with a final number of participants of 24 non-pregnant women and 21 pregnant women. Several pregnant participants were uncomfortable lifting 20% of their current body weight and the load was slightly reduced for them, with an average load of 12.8 (2.5) kg, representing 19.0 (1.9)% body mass for pregnant women and 12.0 (2.3) kg, representing 20.2 (0.1)% body mass for the non-pregnant group.

Trunk angle with respect to vertical, and flexion angles of the knee, shoulder and elbow were determined for the three repetitions of the task for these 45 participants. However, the first attempts at measuring wrist and neck angles showed that it was not possible to determine these angles accurately in a large number of cases using Dartfish^{TM}, and, when they could be determined, the within participant reproducibility was poorer than for the other angles (ranges of greater than 10 degrees in extreme cases) as reported by other authors [16,17]. It was decided not to continue the analysis of these angles with the Dartfish^{TM} software any further, but they were considered in the REBA scores which only require the angle to be put into broad categories.

Table 1

Trunk angle with respect to vertical (flexion is positive) and flexion angles of the knee, shoulder and elbow [mean (SD)] in degrees for the Pregnant (P, $n = 21$) and Non-Pregnant (NP, $n = 24$) groups and p values for the comparison between the two groups, with significance level at $\alpha = 0.05$. Angles are measured in the sagittal plane

Angle	Group	Pick-up	1st Ext.	2nd Ext.	Set down
Trunk	P	83(8)	−16(6)	−14(14)	84(4)
	NP	82(9)	−13(5)	−14(4)	88(6)
	p	0.631	0.051	0.964	*0.037*
Knee	P	50(27)	20(9)	18(6)	25(17)
	NP	66(26)	21(7)	15(5)	36(17)
	p	*0.045*	0.607	0.195	*0.035*
Shoulder	P	71(9)	79(9)	76(8)	72(10)
	NP	70(8)	80(7)	76(7)	76(10)
	p	0.658	0.670	0.766	0.211
Elbow	P	67(10)	80(12)	73(14)	57(15)
	NP	69(9)	76(8)	76(10)	59(12)
	p	0.479	0.301	0.380	0.395

3.1. Joint and trunk angles

The mean and standard deviation for four joint and trunk angles for the four events and the pregnant and non-pregnant groups are reported in Table 1. On average, the trunk was bent forward by more than 80 degrees at pick-up and set-down, and bent backwards by approximately 15 degrees at the two extension events. Trunk angle was similar between pick-up and set-down.

Knee angle was substantially lower at set-down than pick-up for both groups (24.7° at set-down versus 49.7° at pick-up for pregnant women, and 35.5° at set-down versus 65.7° at pick-up for the non-pregnant group). Similarly, knee angle was smaller at the 2nd than 1st extension, but the difference was only a few degrees (17.5° at 1st extension versus 19.7° at 2nd extension for pregnant women, and 15.3° at 1st extension versus 21.0° at 2nd extension for the non-pregnant group).

The repeatability of video digitizing was generally good, with ICCs above 0.8, except in one case (Table 2). The repeatability of arm angles was not as good as that obtained for knee and trunk angles.

The comparison between the three trials by ANOVA showed no significant difference ($p > 0.05$) between the joint angles of the different trials for all joints and both groups. The averages of the standard deviations between trials are presented in Table 3 for the two groups. Trunk angle was the most repeatable for all four events for both groups, while knee flexion at pick-up was the least repeatable. Elbow flexion at pick-up and knee and elbow flexion at set-down also had relatively low repeatability.

Table 2
Repeatability of the evaluation of angles using Dartfish™ software, Intra-class correlation coefficient and standard deviations (degrees) between the three digitizings averaged over the 10 participants

Event \ Angle	Knee	Trunk	Shoulder	Elbow
Max trunk flexion	0.986(2.7)	0.913(2.3)	0.775(3.5)	0.825(4.0)
Max trunk extension	0.871(3.4)	0.907(1.7)	0.844(2.6)	0.795(3.6)

Table 3
Means of the standard deviations (degrees) across the three trials for the Non-Pregnant (NP, $n = 24$) and Pregnant (P, $n = 21$) groups

	Pick-up		1st extension		2nd extension		Set-down	
	NP	P	NP	P	NP	P	NP	P
Knee	10.0	9.6	5.2	4.1	4.3	6.4	7.0	8.3
Trunk	3.0	3.2	2.9	2.6	2.5	2.9	1.9	2.8
Shoulder	5.6	5.8	5.8	6.0	4.3	5.4	5.8	7.4
Elbow	7.7	9.4	5.3	6.1	5.9	6.4	5.5	8.3

3.2. *Comparison between the pregnant and non-pregnant groups*

Results for the significance values from the t-test comparison between the pregnant and non-pregnant groups for each angle are included in Table 1.

It was found that pregnant women flexed their knees significantly less than non-pregnant women at pick up and set-down by 16° and 11°, respectively (Table 1). However, there was no difference in trunk angle with respect to the vertical at pick-up, and pregnant women had their trunks less inclined with respect to the vertical by 3.3° at set-down. There was also a 3.3° difference in trunk angle at the first extension event (pregnant women more inclined in extension) but it did not reach significance.

There was no significant difference in shoulder or elbow posture in the sagittal plane between the two groups for any of the four events.

These results did not change when the non-pregnant group was compared to a group comprising only women more than four months pregnant ($n = 16$).

3.3. *REBA risk level*

In this analysis, scores from all three trials were considered rather than averages because the scores are not continuous data. The REBA scores in this study ranged from 6 to 12 (for a possible range of 1 to 15), indicating a risk level from "Medium" to "Very High" according to the classification (score 4–7: "medium risk level", score 8–10: "high risk level", score 11–15: "very high risk level") proposed by Hignett and McAtamney [13]. The percentages of trials in each of the three highest risk categories are presented in Table 4. These results show that the majority of trials were in the two highest risk categories for all events. Pick-up and set-down events had a larger number of scores in the two highest risk categories than the two extension events. Pick-up also appeared at higher risk than set-down.

The percentage of trials in each category was generally similar between the two groups except for set-down where a lower number of trials were in the "very high" category in the pregnant group.

4. Discussion

The objectives of this study were to determine sagittal plane postures of the trunk and upper extremities at specific events during the task of lifting and lowering a load to be carried on the head and to compare the postures of pregnant and non-pregnant women at these events. An additional objective was to evaluate the risk level for musculo-skeletal disorders based on the REBA criteria [13].

The main results of the study are that 1) the trunk was inclined forward over 80 degrees to pick up and set down the load and knees were bent moderately, 2) the trunk was inclined backwards (extension) up to approximately 15 degrees when placing the load on the head or taking it back down, 3) pregnant women bent their knees significantly less than non-pregnant women when picking up and setting down the load on the stool, and they did not bend their backs more than non-pregnant women, and 4) all four postures require action according to the REBA classification of risk level: pick-up and set-down postures were classified as having a high or very high risk level and would require soon or immediate action, while the two extension postures were classified mostly as medium and high risk levels.

4.1. *Limitations*

The task selected for this study in a laboratory setting is fairly representative of the tasks performed daily by street merchants. A pilot study was undertaken by one of the authors to evaluate the weight carried by the street merchants and showed an average of 28%

Table 4
Percentage of REBA risk scores in each risk level category for the Pregnant and Non-Pregnant groups (number of trials considered: 21×3=63 for the Pregnant group, and 24×3=72 for the Non-Pregnant group). Note: the two lowest REBA categories, negligible (score 1) and low (2–3) are omitted from the table because none of the postures were classified as such

Risk level / Event		Medium (score 4–7) Action: necessary	High (score 8–10) Action: necessary soon	Very high (score 11–15) Action: necessary now
Pick-up	Pregnant	0	33.3	66.7
	Non-Pregnant	0	29.2	70.8
1st Extension	Pregnant	33.3	55.6	11.1
	Non-Pregnant	31.9	65.3	2.8
2nd Extension	Pregnant	17.5	77.8	4.8
	Non-Pregnant	36.1	61.1	2.8
Set-down	Pregnant	0	65.1	34.9
	Non-Pregnant	2.8	31.9	65.3

body weight; therefore the ratio of 20% in this study was below that average but still representative. As pre-pregnancy weight was not available for the pregnant group, we used current weight. Consequently, we had to slightly slacken the criterion for 7 of the 21 pregnant participants, but only one of them carried a load less than 15% her body weight. These participants ranged from 4 to over 9 months of pregnancy. Despite this adjustment for the weight carried, the pregnant women carried on average a larger weight than non-pregnant women because of their higher body weight.

The accuracy of the angles determined using the Dartfish™ software is limited by several factors. The main limitation is the evaluation of three-dimensional angles from the single sagittal view. First, the cameras may not have been perfectly aligned with the sagittal and frontal planes of the participants, and this error is expected to vary from participant to participant. The alignment of the camera with the global vertical is another factor to consider, but misalignment errors are not expected to be more than a few degrees.

The task performed by the participants was symmetrical and occurred mostly in the sagittal plane for the trunk and the lower limbs. However, this was not the case for the upper limbs. At pick-up and set-down, the arms were in slight abduction or adduction, but, when placing and removing the tray on the head, the arms were showing a large degree of abduction. Therefore, the angles presented as flexion in Table 1 should be interpreted as indications of the posture rather than accurate values, particularly for the 1st and 2nd extensions.

4.2. Interpretation

During pick-up and set-down, the participants were in deep trunk inclination of over 80 degrees from vertical, and their knees were in moderate flexion, especially at set-down, indicating a stoop posture.

In a study comparing the lifting technique of women and men working in manual material handling, Plamondon et al. [18] found knee angles of 60° for the lift from 32 cm above ground of the women's group dropping to about 40° for the deposit to the same height, compared to 66° and 36° in this study for the non-pregnant group. The smaller knee flexion at set-up may reflect the fact that the task is not as demanding as pick up. The standard deviations were quite large in both studies, between 17° and 35°. It should be pointed out that in Plamondon's study the participants were taller than in this study, 1.62 m versus 1.59 m, and the load was closer to the ground. Trunk inclination at pick up was also similar, 87° versus 82° in this study. At drop down, trunk inclination decreased to 50°, while in this study it increased to 88°. This is somewhat surprising as the target was lower in Plamondon's study, and it could be due to the nature of the load (i.e. a box versus a somewhat more unstable tray). The pregnant group' trunk inclination was only 1 degree larger than at pick up, and significantly lower than for the non-pregnant group. This could be due to a reduced trunk flexibility because of the increased abdominal volume of pregnant women.

It should also be noted that knee angle had the highest standard deviation between participants of all angles measured in this study, and also the highest standard deviation between the three repetitions of the task for the pick-up and set-down events (Table 3). This suggests that knee flexion was not critical for the task and the participants were not close to their limits. Comparatively, trunk angle had the lowest standard deviation between the three trials from all angles measured for all events (Table 3), and standard deviations between participants were also lower than for knee angle.

The flexion angles for the shoulder and elbow had relatively high standard deviations which may reflect the fact that different patterns could be used to share upper extremity flexion between shoulder and elbow to perform the task.

4.3. *Comparison between the pregnant and non-pregnant groups*

In the pregnant group, seven of the 21 participants were not comfortable lifting the target load while all participants in the control group were. This may simply reflect the fact that using current weight to normalise the load was "unfair" to pregnant women, or differences between the participants of the two groups, given that the pregnant group lifted more on average than the non-pregnant group. However, it could also reflect a decrease in strength due to pregnancy. This was noted in a previous study for back and thigh strength [20] and should be further investigated.

The main difference in posture between the two groups was that pregnant women bent their knees less to pick up the load – by about 16° on average (Table 1) – and to put it down on the stool – by about 10° on average – than non-pregnant women. However, there was no significant difference in trunk angle between the two groups at pick-up. At set-down, there was a significant difference of 3° in trunk angle between groups, and pregnant women bent both their trunk and their knees less than non-pregnant women.

To further investigate the effect of pregnancy on this difference, the correlation coefficient between knee flexion angle and month of pregnancy was calculated. The correlation coefficients were $r = -0.57$ ($p < 0.01$) at pick-up and $r = -0.53$ ($p < 0.05$) at set down; therefore 32% (pick-up) and 28% (set-down) in knee angle variation could be explained by stage of pregnancy. As pre-pregnancy weight was not available, we could not test whether there was also a relation between knee angle and weight gain.

One hypothesis to explain this difference between the groups is that pregnant women avoided bending their knees because of the extra effort needed from the thigh muscles to lift the increased upper body weight. In addition, they may also have avoided the increased instability caused by the larger moment of the upper trunk during this effort. The fact that the weight lifted was based on their pregnant weight, resulting in them lifting a higher load than non-pregnant participants, has likely augmented these effects, possibly contributing to them using a safer technique by flexing their knees less.

The fact that the pregnant group also tended to bend their trunk less (set-down) suggests that they used their arms more to grasp and put down the tray, but no significant differences in shoulder and elbow angles were found, though both angles were lower at set-down for this group, showing more extension of the shoulder and elbow.

4.4. *Risk evaluation*

From REBA, the pick-up posture for both the pregnant and non-pregnant women was found to have the most *very-high* risk cases with a 67% occurrence in pregnant women and a 71% occurrence in non-pregnant women. The set down posture for these two groups had a lower amount of it very-high risk postures with a 35% occurrence in the pregnant group and a 65% occurrence in the non-pregnant group (Table 4). Though similar in posture and load, the two tasks were classified with different levels of risk due to the substantial difference in knee flexion between them (Table 1). Larger knee flexion average at set down also explains the larger percentage of high risk trials for non-pregnant women. Therefore the pregnant women were using a safer technique to lift and put down the load according to REBA.

It was also found that the 1st and 2nd extension postures had a much lower frequency of *very-high* risk cases. The majority of cases were *high* risk with occurrences that ranged from 56% to 78%. The reason for the large decrease in the percentage of it very high risk cases for both groups compared to the pick-up and set-down posture was the large decrease in average trunk and knee flexion.

The very high risk postures that have been associated with musculo-skeletal disorders and found in this study are consistent with other literature, which identified segment flexion as a risk factor of musculo-skeletal disorders [19]. Buckle and Devereux [19] conducted a review that found evidence to support a positive relationship between segments and their postures and the onset of musculo-skeletal disorders of the neck and upper limb.

The recommendation from REBA prescribes that action is necessary to modify the pick-up and set-down tasks immediately. Placing the load on the head is also rated as high risk and requiring prompt action. However, thousands of women perform these tasks repeatedly every day; in many cases the task is even more arduous than what was performed in the laboratory because the load lifted is heavier, more difficult to grasp or because it is positioned on the ground rather than on a stool. Many of the women who perform these tasks are pregnant, teenagers, or aging women, and REBA does not take these states into consideration in evaluation of risk.

These results suggest that an investigation of the prevalence of musculo-skeletal injuries among street merchants is urgently needed. An estimation of joint loads, particularly on the lumbar spine, and frequency of lifting would also give other important information to evaluate risk. If such investigations confirm the results found about risk in this study, preventative measures should be developed, as well as ways to disseminate this knowledge about the target population to protect women from injury. This may be particularly relevant in the case of teenagers who have not completed skeletal growth, pregnant women, and aging women.

5. Conclusions

In this study, four events were selected for postural analysis during the task of lifting a load from a stool to place it on the head for carrying and setting it down onto the stool, based on maximum forward (flexion) or backward (extension) inclination of the trunk. On average, the trunk was inclined forward by more than 80 degrees at pick-up and set-down. Trunk inclination increased slightly between pick-up and set-down for the non-pregnant group and was significantly higher than for the pregnant group. The knees were flexed moderately at pick-up and knee angle was substantially less at set-down than pick-up for both groups. Women extended their trunk by approximately 15 degrees to place the load on their heads and remove it.

The only postural difference between pregnant and non-pregnant women occurred at pick-up and set-down. Pregnant women flexed their knees less than non-pregnant women, most likely to maintain stability despite the larger weight of their upper body and load lifted, but they did not incline their trunk more. They therefore used a safer lifting technique than non-pregnant participants, though they did not bend their backs less.

The postures at all four selected events were classified as “high” or “very high” risk level based on their REBA scores. It is suggested that future research investigates the prevalence of musculo-skeletal injuries among street merchants to confirm these results and lead to guidelines for prevention of injuries.

Acknowledgments

This project was funded by research grants provided by the Natural Sciences and Engineering Research Council, the Human Mobility Research Centre, and the International Society of Biomechanics. We would also like to thank the midwife at the local maternity centre and Ganiath Osseni for their tremendous help in the recruiting phase of this project as well as the numerous students at the INJEPS who helped to make things run smoothly in the lab. Finally we thank Tara Diesbourg for her help with the analysis and Dr. André Plamondon for his comments in the final stages of the analysis and writing.

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