

Original research

Mimicking obesity and pregnancy by adding load mass elicits minor postural oscillations compared to backpack weight carrying.



Hanan Rkain^a, Bruno Vie^b, Yves Jammes^{b,c,*}

^a Laboratory of Physiology, Faculty of Medicine, Mohammed V University, Impasse Souissi, Rabat, Morocco

^b School of Podiatry, 246 Bd de Plombières, 13014, Marseille, France

^c C2VN Inra Inserm, Faculty of Medicine, Aix Marseille University, Bd Pierre Dramard, 13916, Cedex 20, Marseille, France

ARTICLE INFO

Keywords:

Obesity
Posture control
Weight carrying
Upright standing
Healthy subjects

STRUCTURED ABSTRACT

Objective: An excess load mass of anterior or antero-posterior body part is encountered in pregnancy and android obesity, or gynoid obesity, respectively, whereas occupational backpack weight carrying occurs in soldiers, firefighters and school children. We questioned the consequences of different placements of added loads (backpack, anterior or antero-posterior, i.e., around the trunk) on the postural sway during upright standing.

Methods: Thirty six young subjects with normal body weight were examined. Cast iron disks were introduced into the backpack and/or the ventral pockets of a waistcoat (total added load = 30% of body weight). A baropodometric platform measured oscillations of the centre of pressure (CoP) at the end of a 10-min period of upright standing in double limb stance in control condition (no weight carrying) and at the end of each 10-min weight carrying session. A 10-min rest period elapsed between two consecutive carrying sessions.

Results: Backpack carrying elicited the highest changes in postural sway, increasing the CoP surface and length, the velocity of anteroposterior and mediolateral deviations and the magnitude of mediolateral deviations. On the other hand, anterior load mass placement only increased the velocity of changes in the anteroposterior CoP deviation and antero-posterior weight carrying solely increased the mediolateral CoP deviation.

Conclusion: Added load mass mimicking pregnancy, android or gynoid obesity elicits discrete changes in postural control compared to backpack weight carrying which may accentuate the risk of fall during occupational activities.

Clinical trial registration: CPP Sud Méditerranée 1, September 9th 2015, N° 2014-AO1969-38.

1. Introduction

Obesity constitutes a situation of increased weight carrying but the distribution of fat tissues varies between gynoid (female) and android (male) obesity, added weight being distributed around the trunk in the former while it predominantly affects the abdomen and thus the anterior part of the trunk in the later. Several authors have shown that android obesity accentuates the postural sway in upright subject (Hue et al., 2007; Teasdale et al., 2007; Singh et al., 2009; Mignardot et al., 2013). Soldiers (Knapik et al., 2004; Birrell et al., 2007; Heller et al., 2009; Majumdar et al., 2010), firefighters (Park et al., 2015) and school children (Pau and Pau, 2010) have to carry added loads on their back which markedly affect the balance control. Pregnancy is another major cause of prolonged anterior weight carrying. Oliveira et al. (2009) have well described the postural sway changes during upright standing in pregnancy showing a significant increase in anteroposterior

CoP deviations. Also, Krkeljas (2018) confirmed the anterior-posterior postural sway during static condition in pregnant women and showed that the postural changes were attenuated during walking.

We found very few literature data on the comparison of postural changes in relation to the distribution of weight carriage. Two studies have examined the effects of different load mass placement on postural sway (Qu and Nussbaum, 2009; Rugelj and Sevsek, 2011), showing that backpack carriage increased more the postural oscillations than the antero-posterior distribution of added loads. No study has explored in the same subject the differences in posture sway elicited by anterior, posterior or antero-posterior weight carriage. It may be hypothesized that the distribution of weight carrying should modify differently the projection of the centre of mass and in consequence of the centre of pressure (CoP), resulting in different actions on the posture sway. In the present study, the posture sways measured with a baropodometric platform were measured in experimental conditions of anterior, antero-

* Corresponding author. C2VN Inra Inserm, Faculty of Medicine, Aix Marseille University, Bd Pierre Dramard, 13916, cedex 20, Marseille, France
E-mail addresses: hananrkain@yahoo.fr (H. Rkain), bruno.vie@sfr.fr (B. Vie), yves.jammes@univ-amu.fr (Y. Jammes).

posterior or posterior (backpack) weight carrying in normal young subjects.

2. Methods

2.1. Subjects

The French institutional review boards for human studies (ANSM and CPP) approved the protocols and a written consent was obtained from the subjects. Thirty six healthy subjects (25 females, 11 males; mean age: 27 ± 3 y; mean weight: 63 ± 4 kg; mean body mass index: 24 ± 2) were studied. All were free of foot pain and had no antecedent of trauma or surgery of the feet, legs, and spine.

2.2. Posturographic measurements

All control measurements were performed during upright standing in double limb stance with open eyes using a baropodometric platform. A recent review validates the use of baropodometry in postural assessment (Rosario, 2014). During data collection, the subject stayed upright, the arms stretched alongside the trunk with the hands in supinated position. Our software program allowed to record the postural oscillations for 30 s on a 530×600 mm stationary pedobarographic platform (WinPOD, Medicapteurs SA, Toulouse, France), constituted by 2304 (8×8 mm) resistive load cells, and the sampling frequency was 100 image.s^{-1} . We measured the peak plantar pressure (Pmax expressed in g.cm^2) and the surface described by displacements of the centre of pressure (CoP) and its total length of displacement (L), as well as the amplitude and velocity of changes of the CoP deviations in anteroposterior and mediolateral directions. Control measurements with no added weight as well as the sessions with the added weights were repeated twice and we did not measure significant difference in CoP deviations between two consecutive trials.

2.3. Weight carrying

A fisherman's waistcoat with ventral and backpack pockets was used. Cast iron disks of 1, 2, 5, and 10 kg for weightlifting were introduced in the pockets to reach a total added load of 30% of the body weight. Among the subjects, a total of 12–28 kg disks was borne during standing.

2.4. Protocol

After control posturographic measurements with no added weight, the three conditions of weight carrying (posterior, anterior or antero-posterior) were repeated twice at random. Measurements were performed at the end of a 10-min period of weight carrying, and at the end of 10-min rest periods with no added weight, elapsing between two consecutive weight carrying sessions.

2.5. Statistical analyses

All data are given by their mean \pm standard error (SEM) for each condition based on one trial for each participant without gender consideration. Two-factor ANOVAS on gender and added loads were used to compare data measured in the different experimental conditions. When the normality test failed, we used the pairwise multiple comparison procedure (Holm–Sidak method). Significance was accepted when P values was < 0.05 .

3. Results

Figs. 1 and 2 show the absolute values of data measured to depict the postural control. They clearly show that the backpack weight carrying condition exerted the major changes in postural control, while the

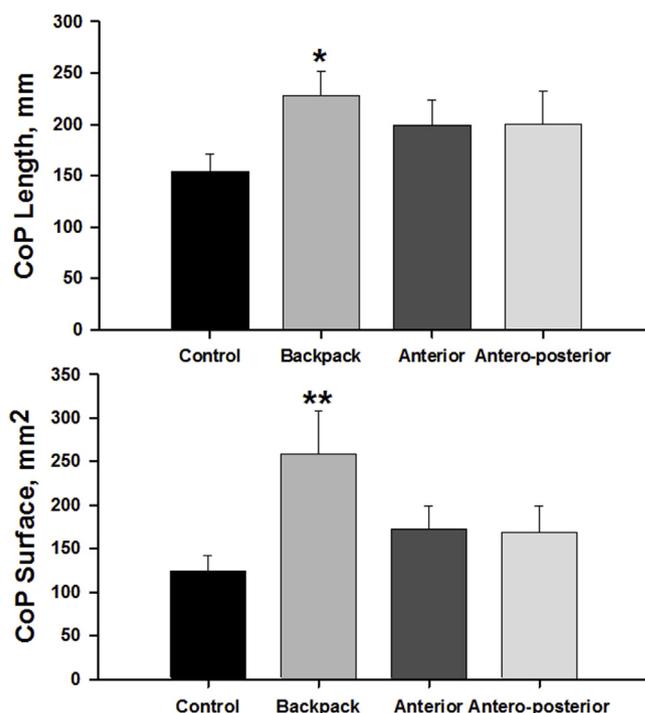


Fig. 1. Comparison between control condition (no added load mass), dorsal (backpack), anterior, and antero-posterior weight carrying of absolute values of the length and surface of centre of pressure (CoP) oscillations. Asterisks show significant differences compared to control (* $p < 0.05$; ** $p < 0.01$).

anterior weight carrying condition only increased the velocity of antero-posterior deviation and antero-posterior weight carrying only affected the mediolateral deviation.

Table 1 allows to compared the magnitude of differences between the changes in postural control measured in control (no weight) and the different weight carrying conditions. Significant intergroup differences were measured, the highest variations in CoP L and S, and mediolateral deviation being measured during backpack weight carrying sessions compared to results obtained for the control condition.

No gender differences between weight induced changes in postural control were measured. The changes in CoP deviations were no more significant 10 min after the weight had been removed in each situation. This allowed to consider data collected 10 min after each weight carrying condition as the reference values for the following one.

Pmax significantly increased by backpack, anterior or antero-posterior weight carrying (Fig. 3) but no significant difference was found between the different placements of added loads.

4. Discussion

The comparison of the postural changes elicited by the different weight carrying conditions shows that anterior or antero-posterior placement of added load mass, mimicking obesity or pregnancy, exerted modest variations of the postural control. On the other hand, backpack carrying elicited the highest changes, increasing both the CoP surface and its length, accentuating the velocity of anteroposterior and mediolateral deviations and the magnitude of mediolateral CoP deviations. We did not find significant gender differences between CoP deviations elicited by weight carrying. This may be explained by the fact that all our subjects were young and sportive resulting in tightening of muscles of their dorsal and abdominal wall. Thus, it may be supposed that the physical consequences of weight carrying on centre of mass displacements could be the same in both sexes.

Previous measurements in male obese individuals have already reported during quiet standing higher postural sway than in non-obese

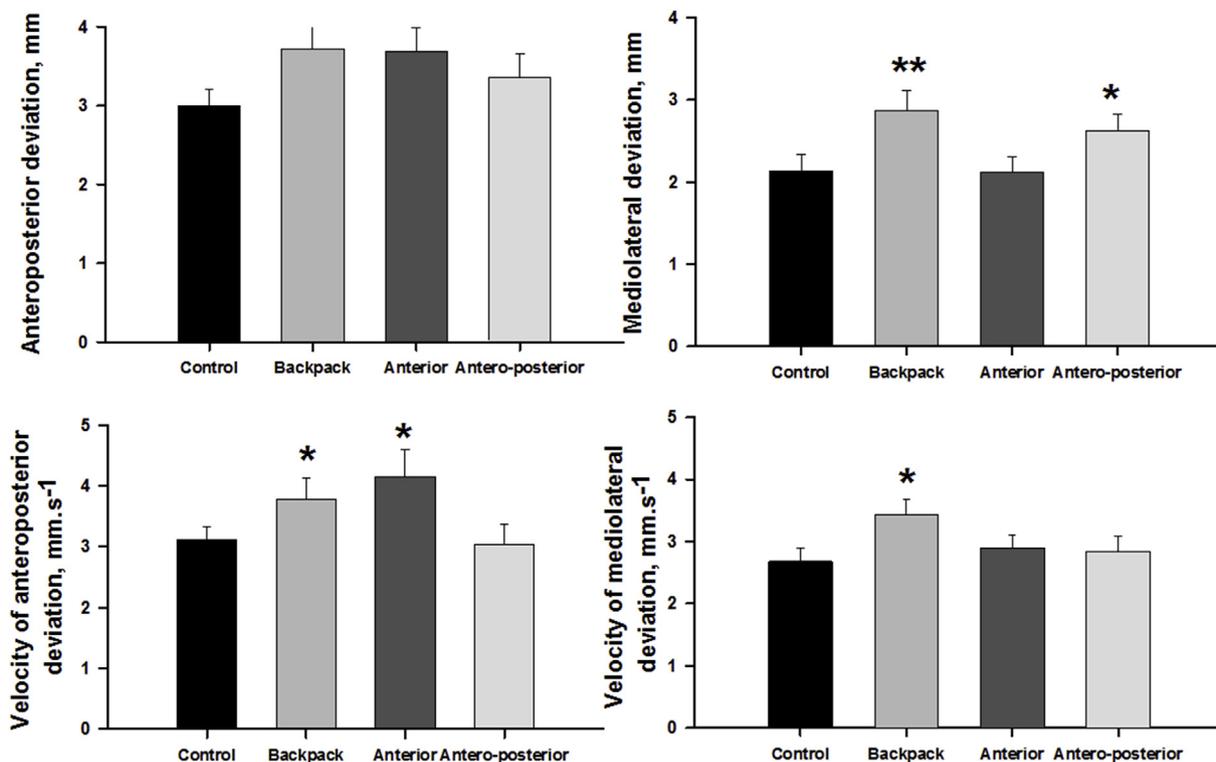


Fig. 2. Comparison between control condition (no added load mass), dorsal (backpack), anterior, and antero-posterior weight carrying of absolute values of the magnitude and velocity of changes in anteroposterior and mediolateral CoP deviations. Asterisks show significant differences compared to control (*p < 0.05; **p < 0.01).

Table 1

Absolute differences (Delta) from control (no mass load) of CoP oscillations in the three conditions of load mass placement. Values are mean ± SEM. Asterisks (*p < 0.05; **p < 0.01) denotes significant difference between placements.

	Backpack	Anterior	Antero-posterior
Delta CoP Length, mm	47 ± 19 *	12 ± 22	15 ± 23
Delta CoP Surface, mm ²	125 ± 39 **	34 ± 22	50 ± 27
Delta anteroposterior CoP deviation, mm	0.57 ± 0.45	0.56 ± 0.33	0.40 ± 0.28
Delta mediolateral CoP deviation, mm	0.66 ± 0.29 *	0.07 ± 0.24	0.49 ± 0.31 *
Delta velocity of anteroposterior CoP deviation, mm.s ⁻¹	0.45 ± 0.34	0.73 ± 0.35	* 0.13 ± 0.24
Delta velocity of mediolateral CoP deviation, mm.s ⁻¹	0.20 ± 0.22 *	0.04 ± 0.23	0.03 ± 0.15

subjects (Singh et al., 2009; Hills et al., 2001; Miller et al., 2001). In obese subjects, Singh et al. (2009) reported that the postural sway during prolonged upright standing was markedly accentuated compared to normal weight subjects but they did not distinguish the consequences of gynoid and android obesities. On the other hand, Hills et al. (2001) have investigated plantar pressure differences between obese and non-obese adults of both sexes during standing and walking protocols. They found higher plantar pressures for obese women (antero-posterior distribution of fat tissue) compared to obese men (prevailing anterior distribution of fat) during upright standing, showing that the android obesity elicited less alterations of the postural control. Also, Miller et al. (2001) reported that obese males showed a less significant number of centre of mass displacements than normal weight individuals undergoing force perturbations. The present data corroborate these observations but our experimental model of obesity

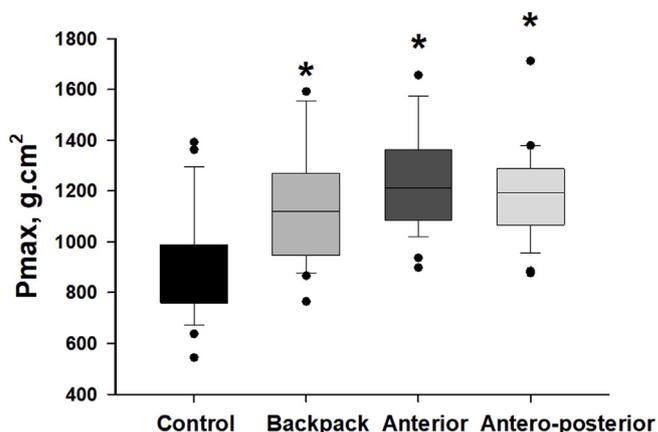


Fig. 3. Peak values of plantar pressure (Pmax) measured in control (no added loads) and the 3 experimental conditions of weight carrying. Asterisk shows that Pmax significantly differed (p < 0.05) between control and weight carrying sessions but no significant difference was measured between the different weight carrying conditions.

does not show significant difference between Pmax values measured during antero-posterior and anterior placement of added loads. Thus, mimicking obesity by added mass loads does not exactly reproduce the pathological circumstances. Indeed, in our experimental study, the increased body weight was transient (10 min) compared to several years (obesity) or several months (pregnancy) of excess weight and, despite the substantial increase in mass load confirmed by the increased Pmax, we only measured minor postural sway in load mass placement condition mimicking the android obesity, the changes only consisting in an increased velocity of changes in the anteroposterior CoP deviation. Obese subjects often suffer from fatigue of leg and trunk muscles (Bollinger, 2017) and muscular fatigue elicits perturbation of the

postural control (Corbeil et al., 2003). Fatigue cannot occur in our young healthy subjects where the weight carrying sessions lasted maximally 10 min. Thus, the postural sway here reported probably result from a forward projection of the centre of pressure (CoP), increasing its displacements with spatiotemporal desynchronization (Winter et al., 1990).

We did not find literature data on the comparison of posture changes elicited by backpack, anterior or antero-posterior weight carrying in healthy individuals. Rugelj and Sevsek (2011) examined the changes in postural sway elicited by carrying added weight in backpack or a waist jacket (antero-posterior load mass) showing that “carrying weight in a backpack increases postural sway with increasing weight whereas carrying weight in a waist jacket does not influence the amount of postural sway ». In fact, most of studies have focused on backpack weight carrying. This situation induces a backward translation of the centre of mass which accentuates the postural sway when standing upright (Knapik et al., 2004; Qu and Nussbaum, 2009; Winter et al., 1990). We corroborate these findings. The consequences on backpack weight carrying on the foot sole sensitivity have been published (Jammes et al., 2018), showing that weight carrying reduced the sensory pathways from the foot sole. The foot sole sensitivity playing a key role in posture control (Forbes et al., 2018) it may be supposed that this reduction of sensory pathway could partly explain the accentuated postural sway.

5. Conclusion

In conclusion our data may help to understand the collateral effects of transient (occupational) or prolonged (obesity and pregnancy) added body weight bearing. We showed that the magnitude of changes in CoP deviations was significantly higher during backpack weight carrying than in other placements of load mass, mimicking obesity or pregnancy. Thus, obesity or pregnancy could be responsible for discrete alterations of the postural control compared to the occupational activities of soldiers and firefighters. Backpack weight carrying could major health risks accompanying prolonged standing as previously reported by Waters and Dick (2015).

Funding sources

This work was only supported by the School of Podiatry Marseille

Disclosure

The authors declared no conflict of interest.

Acknowledgments

The authors acknowledge the students of the School of Podiatry who

participated to the present study: Maureen Azoulay, Imane Melhaoui, and Kelly Amar.

References

- Birrell, S.A., Hooper, R.H., Haslam, R.A., 2007. The effect of military load carriage on ground reaction forces. *Gait Posture* 26, 611–614.
- Bollinger, L.M., 2017. Potential contributions of skeletal muscle contractile dysfunction to altered biomechanics in obesity. *Gait Posture* 56, 100–107.
- Corbeil, P., Blouin, J.S., Bégin, F., Nougier, V., Teasdale, N., 2003. Perturbation of the postural control system induced by muscular fatigue. *Gait Posture* 18, 92–100.
- Forbes, P.A., Chen, A., Blouin, J.S., 2018. Sensorimotor control of standing balance. *Handb. Clin. Neurol.* 159, 61–83.
- Heller, M.F., Challis, J.H., Sharkey, N.A., 2009. Changes in postural sway as a consequence of wearing a military backpack. *Gait Posture* 30, 115–117.
- Hills, A.P., Hennig, E.M., McDonald, M., Bar-Or, O., 2001. Plantar pressure differences between obese and non-obese adults: a biomechanical analysis. *Int. J. Obes. Relat. Metab. Disord.* 25, 1674–1679.
- Hue, O., Simoneau, M., Marcotte, J., Berrigan, F., Doré, J., Marceau, P., Marceau, S., Tremblay, A., Teasdale, N., 2007. Body weight is a strong predictor of postural stability. *Gait Posture* 26, 32–38.
- Jammes, Y., Ferrand, E., Fraud, C., Boussuges, A., Weber, J.P., 2018. Adding body load modifies the vibratory sensation of the foot sole and affects the postural control. *Mil. Med. Res.* 5, 28. <https://doi.org/10.1186/s40779-018-0175-4>.
- Knapik, J.J., Reynolds, K.L., Harman, E., 2004. Soldier load carrying: historical, physiological, biomechanical, and medical aspects. *Mil. Med.* 169, 45–56.
- Krkelj, Z., 2018. Changes in gait and posture as factors of dynamic stability during walking in pregnancy. *Hum. Mov. Sci.* 58, 315–320.
- Majumdar, D., Pal, M.S., Majumdar, D., 2010. Effects of military load carrying on kinematics of gait. *Ergonomics* 53, 782–791.
- Mignardot, J.B., Olivier, J., Promayon, E., Nougier, V., 2013. Origins of balance disorders during a daily living movement in obese: can biomechanical factors explain everything? *PLoS One* 8, e60491. <https://doi.org/10.1371/journal.pone.0060491>.
- Miller, E.M., Sara, L., Matrangola, L., Michael, L., 2001. Madigan. Effects of obesity on balance recovery from small postural perturbations. *Ergonomics* 54, 547–554.
- Oliveira, L.F., Vieira, T.M., Macedo, A.R., Simpson, D.M., Nadal, J., 2009. Postural sway changes during pregnancy: a descriptive study using stabilometry. *Eur. J. Obstet. Gynecol. Reprod. Biol.* 147, 252–258.
- Park, H., Kim, S., Morris, K., Moukperian, M., Moon, Y., Stull, J., 2015. Effects of firefighters' personal protective equipment on gait. *Appl. Ergon.* 48, 42–48.
- Pau, M., Pau, M., 2010. Postural sway modifications induced by backpack carriage in primary school children: a case study in Italy. *Ergonomics* 53, 872–881.
- Qu, X., Nussbaum, M.A., 2009. Effects of external loads on balance control during upright stance: experimental results and model-based predictions. *Gait Posture* 29, 23–30.
- Rosario, J.L., 2014. A review of the utilization of baropodometry in postural assessment. *J. Bodyw. Mov. Ther.* 18, 215–219.
- Rugelj, S., Sevsek, F., 2011. The effect of load mass and its placement on postural sway. *Appl. Ergon.* 42, 860–866.
- Singh, D., Park, W., Levy, M.S., Jung, E.S., 2009. The effects of obesity and standing time on postural sway during prolonged quiet standing. *Ergonomics* 52, 977–986.
- Teasdale, N., Hue, O., Marcotte, J., Berrigan, F., Simoneau, M., Doré, J., Marceau, P., Marceau, S., Tremblay, A., 2007. Reducing weight increases postural stability in obese and morbid obese men. *Int. J. Obes. Relat. Metab. Disord.* 31, 153–160.
- Waters, T.R., Dick, R.B., 2015. Evidence of health risks associated with prolonged standing at work and intervention effectiveness. *Rehabil. Nurs.* 40, 148–165.
- Winter, D.A., Patla, A.E., Frank, J.S., 1990. Assessment of balance control in humans. *Med. Prog. Technol.* 16, 31–51.