THE UNIVERSITY OF NORTHAMPTON

Article

Title: Effects of external loads on postural sway during quiet stance in adults aged 20–80 years

Creators: Hill, M.W., Duncan, M.J., Oxford, S.W., Kay, A. D. and Price, M.J.

DOI: 10.1016/j.apergo.2017.08.007

Example citation: Hill, M.W., Duncan, M.J., Oxford, S.W., Kay, A. D. and Price, M.J. (2017) Effects of external loads on postural sway during quiet stance in adults aged 20–80 years. *Applied Ergonomics.* **66**, pp. 64-69. 0003-6870.

It is advisable to refer to the publisher's version if you intend to cite from this work.

Version: Accepted version

Official URL: http://dx.doi.org/10.1016/j.apergo.2017.08.007

Note:

http://nectar.northampton.ac.uk/9796/

TITLE

Effects of external loads on postural sway during quiet stance in adults aged 20 – 80 years

AUTHORS

Hill MW[1], Duncan MJ[1], Oxford SW[1], Kay, AD[2], Price MJ[1]

AFFILIATIONS

[1] Centre for Applied Biological and Exercise Sciences, Coventry University, Priory Street, Coventry, CV1 5FB, UK

[2] Ageing Research Centre, University of Northampton, Boughton Green Road, Northampton, NN2 7AL, UK

CORRESPONDING AUTHOR

Dr. Mathew Hill

Centre for Applied Biological and Exercise Sciences

Coventry University

Priory Street

Coventry

CV1 5FB, UK

Matt.hill@coventry.ac.uk

1. INTRODUCTION

Postural control in quiet standing is a complex function that involves maintaining the vertical position of the centre of mass (COM) within the base of support (Paillard, 2012). The ability to maintain an upright stance is an essential pre-requisite for gait, initiation of voluntary movement and for activities of daily living (Vuillerme et al. 2002). In order to perform a postural task, the central nervous system must continuously integrate and re-weigh information from different sensory systems (vision, vestibular and somatosensory) and modulate commands to the neuromuscular system (Gurfinkel et al. 1995). The performance of the postural control system can be quantitatively estimated by measuring the ability to minimise postural sway during quiet stance (Paillard and Noe, 2015). By using centre of pressure (COP) measures, it has been shown that postural sway increases when the difficulty of the task increases, for example, by altering the support surface size and shape (Era et al. 2006), decreasing the quality of sensory input (Cornilleau-Peres et al. 2005), or diminishing neuromuscular control with muscle fatigue (Paillard, 2012).

Postural sway during quiet standing can additionally be affected by external loading (Rosker et al. 2011). Load bearing during standing is an important aspect of many daily and occupational activities (Rugelj and Sevesk 2011). The existing literature has suggested that holding external loads at or above the COM (e.g. weights positioned at the waist, back or shoulders) alters the mass-inertia characteristics of the body, since the application of the load increased postural sway during quiet standing (Heller et al. 2009; Qu and Nussbaum 2009; Rugelj and Sevsek 2011; Shiffman et al. 2006). For example, carrying a backpack elicits a posterior shift in the COM, which is compensated for by forward trunk lean to move the COM anteriorly (Palumbo et al. 2001). The inverted pendulum model states that the stability of a rigid body is inversely related to the height of its COM above the base of support (Winter et al. 1998). Thus, when the position of the COM is elevated (i.e. carrying a backpack), the body has less stability and an increase in postural sway is observed.

Despite the prevalence of holding loads in the hands (i.e., grocery bags), little is known about the extent to which carrying asymmetrical loading affects postural sway parameters. Carrying a load in the hand, such as a grocery bag, could be expected to affect the COM differently to how a backpack would. Indeed, Zultowski & Aruin (2008) reported an increase in mediolateral COP as a result of holding an asymmetrical load (20% body mass) among young individuals. Holding asymmetrical loads may consequently have important implications for older people because mediolateral aspects of postural sway have predictive value for fall incidence (Era et al. 2006; Maki, Holliday and Topper 1994). More recently, it has been shown that holding a relatively light load in the hand (1.5 and 3.0 kg) did not alter postural sway in young or older females (Bampouras and Dewhurst 2016). The above study assessed symmetrical load and asymmetrical load in the preferred hand and included only young and older females, limiting the generalisability of their findings to both genders across the entire adult age spectrum. When carrying or holding loads, individuals are likely to interchange between the preferred and non-preferred hand, to offset fatigue effects of prolonged load carriage and to allow the opposite

hand to be free for other activities (Wang & Gillette, 2017). From this perspective, it is important to consider postural sway while holding loads with the preferred and non-preferred hand.

Given the limitations in the existing scientific literature, the purpose of this study was to determine the effects of external loads carried symmetrically and asymmetrically (in the preferred and non-preferred hand) on postural sway in males and females aged 20 – 80 years. Considering that this type of loading comprises an important activity of daily life and is frequently practiced by adults of all ages, examining the effects of holding external loads across the lifespan has clear relevance. We hypothesised that postural sway without holding a load (control condition) would systemically increase from 30 to 80 years (Era *et al.* 2006). We also hypothesised, that asymmetrical loading would increase postural sway (Zultowski & Aruin, 2008), particularly among older adults (60 – 80 years).

2. METHODS

2.1 Participants

Sixty-five healthy adults (females, $n = 35$) gave their written informed consent to participate in this study. Recruitment continued until a minimum of ten participants were obtained for each decade from 20 to 80 years (Table 1). All participants were healthy with no previous history of neurological, orthopaedic, musculoskeletal and/or cardiovascular, pulmonary or metabolic diseases. All participants could walk without the use of an assistive device and were independently living and engaging in recreational daily activities. The procedures of the study were approved by the ethics committee of Coventry University, and experiments were carried out according to the Declaration or Helsinki (1964).

*** **TABLE 1 ABOUT HERE** ***

2.2 Postural sway measures

To examine postural sway each participant performed quiet standing tasks on a force platform (AMTI, AccuGait, Watertown, MA) for 30 s. The force platform was calibrated in accordance with the manufacturer's recommendations. Data were sampled at 100 Hz (AMTI, Netforce, Watertown, MA) and the total displacement of centre of pressure (COP) in the anteroposterior (COP_{AP}) and mediolateral (COP_{ML}) directions, and COP path length (COP_L) (all cm) were subsequently calculated (AMTI, BioAnalysis, Version 2.2, Watertown, MA) and served as measure of postural sway. All forces were filtered with a 4th order low-pass Butterworth filter with a cut off frequency of 6 Hz. To ensure continuity between bipedal trials, unshod foot position was standardised at a distance of 3 cm between the medial extremities of the posterior side of the calcaneus with feet at a self-selected angle. In an attempt to reduce within-session variability a tracing of the participant's feet was made on A3 paper for use in subsequent trials.

Following a single familiarisation trial for each task, participants performed four standing postural tasks: (1) bipedal stance while holding a grocery bag in the right hand, (2) bipedal stance while holding a grocery bag in the left hand, (3) bipedal stance while holding a grocery bag in both hands, (4) bipedal

stance without holding bags (CON). All tasks were performed with the eyes open. The order of task conditions were randomly assigned. Randomisation was done using Research Randomizer, a program published on a publicly accessible official website (www.randomizer.org). A total of three trials were recorded consecutively for each condition and the mean of these trials was used in subsequent analysis. Participants could step off the plate and rest between tests. In order to avoid unnatural postural sway, internal focus of attention and restriction of exploratory behaviour, participants were not asked to stand as still as possible (Lajoie et al. 2016). Instead, participants were asked to minimise movements of the grocery bag (i.e. external focus). Participants' arms were left to hang freely by their sides during unloaded trials. When standing quietly participants were instructed to gaze at a target 1.5 m away, which was adjusted to the eye level of each individual. The load used consisted of circular metal weights of varying dimensions (~12 x 2 cm), held in a reusable grocery bag made from woven synthetic fibres (dimension; 34 cm x 38 cm x 16 cm; volume; 21.89 L). All participants held the same grocery bag. We chose to normalise bag mass to a percentage of total body mass to allow comparisons to be made with previous studies (i.e., Zultowski and Aruin 2008). Throughout all tests, the investigator stayed close to the participants to prevent falling but without interfering with postural sway.

2.4 Data analysis

Statistical analyses were carried out using SPSS version 20.0 software (IBM Inc., Chicago, IL). For all analyses, normality (Shapiro–Wilk test) and homogeneity of variance/sphericity (Levene test) were performed and confirmed prior to parametric tests. Differences between age groups when holding bags were examined using a two-way (age $\times$ condition) repeated measures analysis of variance (ANOVA). Where significant differences were detected, post hoc analyses with Bonferroni-adjusted α were conducted to determine the location of these differences. Cohen's *D* effect sizes (ES) are reported for post hoc comparisons with an effect size of 0.2, 0.6, 1.2 and 2.0 indicating small, medium, large and very large effects, respectively. Associations between COP outcome measures and anthropometrics (height, mass, BMI) were assessed using Pearson's correlation. Associations are reported by their correlation coefficient and their level of statistical significance. Statistical significance was accepted at $P \leq 0.05$ for all tests with all outcome measures reported as mean ± standard deviation (SD).

3. RESULTS

Results from ANOVA for COP_L revealed significant group ($F_{(5,216)} = 18.441$, $P \leq 0.001$) and condition ($F_{(3,216)} = 8.312$, $P \leq 0.001$) effects, but a non-significant group $\times$ condition interaction ($F_{(15,216)} = 1.228$, $P = 0.252$). However, ANOVA revealed significant group $\times$ condition interactions for COP_{AP} ($F_{(15,216)} = 1.734$, $P = 0.046$) and COP_{ML} ($F_{(15,216)} = 2.440$, $P = 0.003$). Post-hoc pairwise comparison showed significant differences in all COP measures between CON and holding loads in the right, left and both hands among the 60-69 and 70-79 year groups (all $P \leq 0.05$) (Fig. 1-3). All COP measures were significantly greater during CON compared to when holding loads. The 60-69 and 70-79 year groups exhibited significantly greater COP_L compared to all other age groups during CON only (all $P \leq 0.05$) (Fig. 1). With the exception of the 60-69 year group, all groups showed significantly less COP_{ML}

compared to the 70-79 year group during CON (Fig. 3). Post-hoc pairwise comparison also showed significant differences in COP_{AP} between the 60-69 and 70-79 year groups compared to all other age groups during all conditions (all $P \le 0.05$) (Fig. 2). There were no significant correlations between height, mass and BMI and postural sway outcome measures (all $P \ge 0.05$) or delta change in postural sway outcome measures (all $P \ge 0.05$).

*** FIGURE 1 ABOUT HERE ***
*** FIGURE 2 ABOUT HERE ***
*** FIGURE 3 ABOUT HERE ***

4. DISCUSSION

This study investigated the influence of holding symmetrically and asymmetrically distributed loads on postural sway during quiet standing across the adult lifespan. The main findings are indicative of external loading eliciting reductions in COP measures of postural sway, which were observed by the sixth decade. To the best of our knowledge, this is the first experimental evidence that asymmetrical and symmetrical loading below the body's COM elicits reductions in postural sway across a wide older age spectrum (60 – 80 years). The reductions in postural sway may be interpreted as a favourable adaptive response since a smaller displacement of the COP is indicative of a more precise control of postural sway (Perrin et al. 1999) and a smaller path length indicates a lower energy expenditure (Gauchard et al. 2002). From this perspective, carrying an external load in the hands, as would be experienced during daily and occupational activities (i.e. shopping for groceries), may reduce the regulatory activity required to maintain postural sway during standing (Bampouras and Dewhurst 2016). Alternatively, holding a load may have imposed new biomechanical constraints causing a decrease in stability. For example, the smaller COP path length (reflecting a slower COP velocity) observed in the present study may be due to motor latencies as a result of increased inertia imposed by holding additional loads. From this perspective, holding a load in the hand may have restricted and/or delayed postural reactions.

To date, the literature investigating the effect of holding loads on postural sway in adults is rather limited. It is focussed primarily on holding external loads at or above the COM (e.g. weights positioned at the waist, back or shoulders) (Heller et al. 2009; Qu and Nussbaum 2009; Rugelj and Sevsek 2011; Shiffman et al. 2006). We initially hypothesised that asymmetrical external loading would increase postural sway among older people, particularly in the mediolateral plane. For instance, Zultowsk and Aurin (2011) investigated the effects of carrying 10% or 20% of their body weight in a briefcase or single strap bag/purse on postural sway in young adults. They found that holding an asymmetrical load corresponding to 20% of individuals body mass increased mediolateral postural sway, but holding a load at 10% body mass had no effect on postural sway. The present study shows a decrease in postural sway among the two oldest cohorts (60-69 and 70-79 years) when holding loads in the preferred, non-preferred hand or in both hands. In agreement with the present findings, Bampouras and Dewhurst (2016) also reported that holding a light external load in the preferred or both hands (1.5 – 3 kg) elicited

significant reductions in the mean COP velocity in older, but not young adults. The present study is novel in that we show that the decrease in postural sway while holding a light external load are unique to older people as no changes were observed in young or intermediate age groups. The discrepancy between the present results and those reported by Zultowsk and Aurin (2011) are likely attributed to load magnitude. The lighter load utilised in the present study and that by Bampouras and Dewhurst (2016) may not have been sufficient to elicit large lateral displacements in the horizontal position of the COM. Instead, with the application of relatively light loads, participants are able to lean in the opposite direction, correcting for any shifts in the COM as a result of asymmetrical loading (Bampouras and Dewhurst 2016). We are precluded from confirming such an adaptive postural mechanism without the use of complimentary muscle activity or kinematic data.

Overall, several neural and/or mechanical mechanisms may account for the reductions in postural sway when holding a light load among older adults. Blaszczyk et al. (2009) reported that there was a negative correlation between body mass and postural sway indices. They showed a marked decrease in postural sway in obese patients compared to lean controls. Our results however, do not confirm these findings. In the present study, we found that none of the COP measures, or the delta changes in COP measures correlated with height, mass or BMI. The discrepancy between the results of the present study and those of Blaszczyk et al. (2009) are likely explained by the range in BMI of the cohorts. The participants in the present study were relatively well matched for BMI (24 – 31) compared to a rather large range (21 – 44) in the Blaszczyk et al. (2009) study. Thus, it is plausible that the static posturography method utilise din the present study may not be sensitive enough to detect changes in postural sway as a result of BMI.

A mechanism that should not be ruled out as a potential contributor to reduced postural sway in older but not younger and intermediate age groups is the additional sensory input from holding the bag. For example, previous studies showed that holding a stick parallel to the ground reduces postural sway by up to 25% (Ustinova and Langenderfer 2013; VanderHill et al. 2014), which represents a similar amount to the present study. A hand holding an external object (i.e., bag) moving in the same direction as the body may create shear forces than can contribute to reduced postural sway (Krishnamoorthy et al. 2002). While the additional sensory supplementation concept may partly explain the present findings, it should be noted that the reductions in postural sway reported by Ustinova and Langenderfer (2013) and VanderHill et al. (2014) were observed in young and intermediate age groups and therefore do not relate well to the present data in older people. An explanation for the inconsistent changes in postural sway between young/intermediate and older adults in our study is the presence of a floor effect. For example, postural sway in the young and intermediate groups may have been close to the 'physiological minimum'. Postural sway in older people has more room to improve, as evidenced from the unloaded condition (CON), and thus changes are more visible.

The functional integration approach for supra-postural tasks provides the most likely explanation for the current findings, which suggests the central nervous system controls two separate tasks as a single

task, in which the performance of one task (i.e. holding bags) facilitates the performance of the other task (i.e. postural sway). For example, reductions in postural sway can be observed under external focus conditions in young and older adults (Chiviacowsky, Wulf and Wally 2010; McNevin, Weir and Quinn 2013; Wulf et al. 2004). In the present study, we specifically avoided instructions of internal focus of attention by asking participants to "minimise movements of the grocery bag". The advantage of an external focus as opposed to internal focus of attention has been explained as resulting from more automatic and reflexive control processes (McNevin and Wulf 2002). If external focus of attention promotes the use of more automated motor control processes and less conscious control, one might expect faster reactions to postural sway, enhancing stability (Wulf, McNevin and Shea 2001).

The current study has several limitations including the relatively small sample size that precludes us from generalising our findings to the wider population and examining gender differences. The latter point is important because males and females have different anthropometrics and postural sway. Furthermore, we only assessed the application of a relatively light external load (5% body mass) on postural sway. Holding heavy loads (i.e., 20% body mass) increases mediolateral postural sway in healthy young adults (Zultowsk and Aurin, 2011) and may consequently have important implications for older people because mediolateral aspects of postural sway have predictive value for fall incidence (Maki et al. 1994; Piirtola and Era, 2006). Furthermore, we used the same dimension bag for all participants, regardless of their height. For older adults with a shorter height, the load would have been closer to the ground which would likely elicit a greater stabilising effect than for taller adults. Finally, postural sway was assessed under static conditions only. As most falls occur during ambulation in the elderly (Talbot et al. 2005), in future studies it would be valuable to incorporate dynamic activities such as gait initiation, treadmill walking, or perturbed stance to improve the 'real life' application of these findings. This is important, because if the stance is perturbed, a torsion effect would be created, making recovery more difficult (Bampouras and Dewhurst 2016).

CONCLUSIONS

In conclusion, our findings indicate that holding symmetrically and asymmetrically distributed external loads did not increase postural sway among adults aged 20 – 80 years. Instead, holding a relatively light load in the hands reduced both directional and distance/velocity measures of postural sway among the two oldest age groups. The reduction in postural sway among the older age groups could be interpreted as a favourable postural adaptation since an increases in postural sway can prospectively predict fall risk among older adults (Johansson et al. 2017). The reductions in postural sway in our study (~20%) were more modest than the effect of a light touch of a stationary surface (~50%) (Albertsen et al. 2010) but similar to the effect of holding a stick parallel to the ground (11-25%) (Ustinova and Langenderfer, 2013; VanderHill et al. 2014) or a grocery bag (Bampouras and Dewhurst 2016). In future studies, it would be valuable to examine the effects of heavy external loads on postural sway among older people.

REFERENCES

Albertsen, IM, Temprado, JJ, Berton, E., 2010. Effect of haptic supplementation on postural stabilization: a comparison of fixed and mobile support conditions. Hum Mov Sci 29, 999–1010.

Bampouras, TM, Dewhurst S., 2016. Carrying shopping bags does not alter static postural stability and gait parameters in healthy older females. Gait Posture 46, 81-85.

Błaszczyk, JW, Cieślinska-Świder, J, Plewa M, Zahorska-Markiewicz, B, Markiewicz, A., 2009. Effects of excessive body weight on postural control. J Biomech 42, 1295-1300.

Chiviacowsky, S., Wulf, G., Wally, R., 2010. An external focus of attention enhances balance learning in older adults. Gait posture 32, 572-575.

Cornilleau-Pérès, V., Shabana, N., Droulez, J., Goh, J. C. H., Lee, G. S. M., & Chew, P. T. K. 2005. Measurement of the visual contribution to postural steadiness from the COP movement: methodology and reliability. Gait Posture, 22, 96-106.

Era, P., Sainio, P., Koskinen, S., Haavisto, P., Vaara, M., Aromaa, A., 2006 Postural balance in a random sample of 7,979 subjects aged 30 years and over. Gerontology 52, 204-213.

Gauchard, G.C., Gangloff, P., Vouriot, A., Mallié, J.P., Perrin, P.P., 2002. Effects of exercise-induced fatigue with and without hydratation on static postural control in adult human subjects. Int J Neurosci 112, 1191–1206.

Gurfinkel, V. S., Ivanenko, Y. P., Levik, Y. S., & Babakova, I. A. 1995. Kinesthetic reference for human orthograde posture. Neuroscience 68, 229-243.

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.

Krishnamoorthy, V, Slijper, H, Latash, ML., 2002. Effects of different types of light touch on postural sway. Exp Brain Res 147, 71-79.

Lajoie, Y., Richer, N., Jehu, D.A., Polskaia, N., Saunders, D., 2016. Letter to the Editor: On "Advantages and disadvantages of stiffness instructions when studying postural control" by CT Bonnet: You just can't win: Advantages and disadvantages of the postural stability requirement. Gait Posture 46: 215-218.

Maki, B.E., Holliday, P.J., Topper, A.K. 1994. A prospective study of postural balance and risk of falling in an ambulatory and independent elderly population. J Gerontol 49, M72-M84.

McNevin, N., Wulf, G., 2002. *Attentional focus on supra-postural tasks affects postural control. Hum Mov Sci 21, 187–202.*

McNevin, N., Weir, P., Quinn, T. 2013. Effects of attentional focus and age on suprapostural task performance and postural control. Research Q Exerc Sport 84, 96-103.

Melzer, I., Benjuya, N., Kaplanski, J. 2004 Postural stability in the elderly: a comparison between fallers and non-fallers. Age Ageing, 33, 602–607.

Paillard, T., 2012. Effects of general and local fatigue on postural control: a review. Neurosci Biobehav Rev 36, 162-176.

Paillard, T., & Noé, F. 2015. Techniques and methods for testing the postural function in healthy and pathological subjects. Biomed Research Int*, doi: 10.1155/2015/891390.

Palumbo, N., George, B., Johnson, A., Cade, D. 2003. The effects of Backpack load carrying on dynamic balance as measured by limits of stability. Work 16, 123-129.

Perrin, P.P., Gauchard, G.C., Perrot, C., Jeandel, C., 1999. Effects of physical and sporting activities on balance control in elderly people. Br J Sports Med 33, 121-126.

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.

Rosker, J., Markovic, G., Sarabon, N., 2011. Effects of vertical center of mass redistribution on body sway parameters during quiet standing. Gait Posture 33, 452-456.

Rugelj, D., Sevšek, F., 2011. The effect of load mass and its placement on postural sway. Appl Ergon 42, 860-866.

Schiffman, J.M., Bensel, C.K., Hasselquist, L., Gregorczyk, K.N., Piscitelle, L., 2006. Effects of carried weight on random motion and traditional measures of postural sway. Appl Ergon 37, 607-614.

Talbot, L.A., Musiol, R.J., Witham, E.K., Metter, E.J., 2005. Falls in young, middle-aged and older community-dwelling adults: perceived cause, environmental factors and injury. BMC Public Health 5, 86.

Ustinova, K.I., Langenderfer, J.E., 2013. Postural stabilization by gripping a stick with different force levels. Gait Posture 38, 97-103.

VanderHill, MS, Wolf, EE, Langenderfer, JE, Ustinova, KI., 2014. The effect of actual and imaginary handgrip on postural stability during different balance conditions. Gait Posture 40, 652-657.

Vuillerme, N., Forestier, N., & Nougier, V. 2002. Attentional demands and postural sway: the effect of the calf muscles fatigue. Med Sci Sports Exerc 34, 1907-1912.

Wang, J, Gillette, J., 2017. Carrying asymmetric loads during stair negotiation. Gait Posture, 53, 67-72.

Winter, D.A., Patla, A.E., Prince, F., Ishac, M., Gielo-Perczak, K., 1998. Stiffness control of balance in quiet standing. J Neurophysiol 80, 1211-1221.

Wulf, G., McNevin, N., Shea, CH., 2001. The automaticity of complex motor skill learning as a function of attentional focus. Q J Exp Psychol A 54, 1143–1154.

Wulf, G., Mercer, J., McNevin, N., Guadagnoli, M.A., 2004. Reciprocal influences of attentional focus on postural and suprapostural task performance. J Mot Behav 36, 189-99.

Zultowski, I., Aruin, A., 2008. Carrying loads and postural sway in standing: the effect of load placement and magnitude. Work 30, 359-368.

Table 1: Participant demographics for each decade for 20 – 80 years

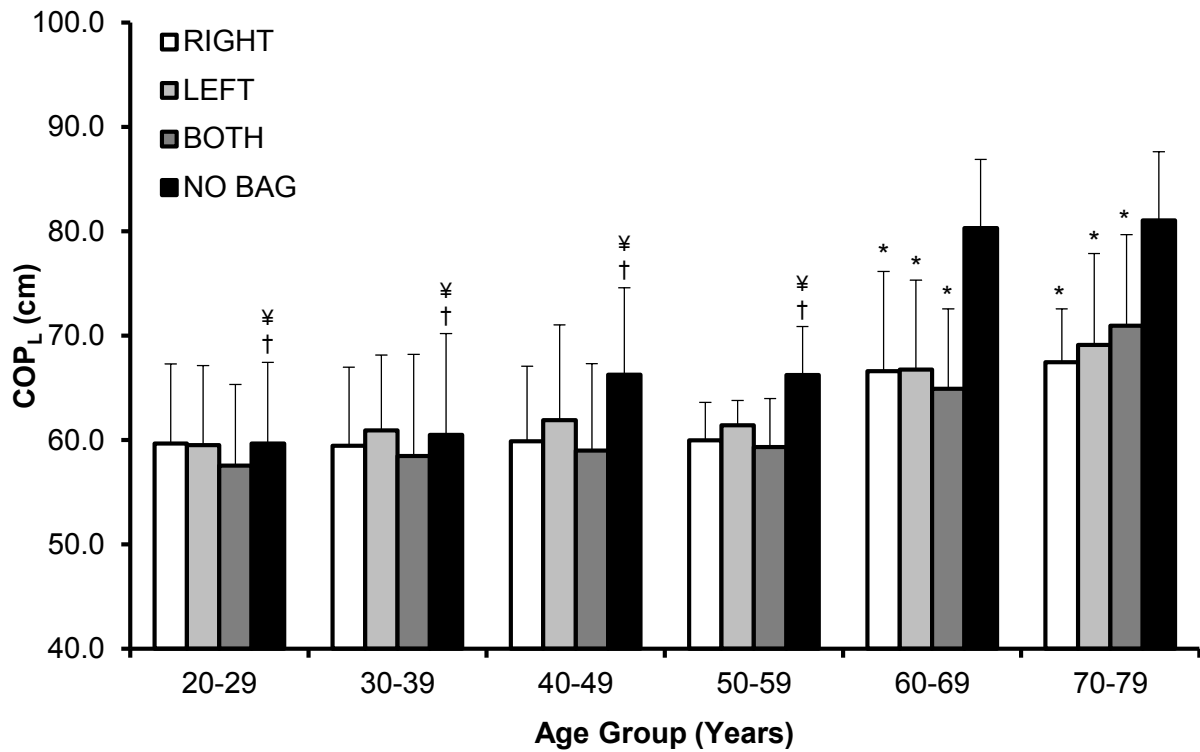| Decade (Years)	Sample (*n*)	Gender (M / F)	Age (Years) (Range)	Height (cm)	Mass (kg)	Bag Mass (kg)	BMI
20 – 29	13	5 / 8	25.5 ± 2.3 (20 – 28)	170.6 ± 8.7	72.0 ± 14.4	3.6 ± 0.7	24.2 ± 3.4
30 – 39	10	6 / 4	33.8 ± 2.7 (33 – 38)	173.8 ± 4.1	73.6 ± 7.1	3.7 ± 0.4	24.9 ± 2.8
40 – 49	11	5 / 6	43.4 ± 2.9 (42 – 49)	172.4 ± 7.4	72.7 ± 13.0	3.6 ± 0.7	24.3 ± 3.1
50 – 59	10	5 / 5	53.0 ± 2.0 (52 – 56)	170.3 ± 7.6	74.9 ± 6.8	3.7 ± 0.3	27.3 ± 4.8
60 – 69	10	4 / 6	63.8 ± 1.9 (62 – 67)	163.1 ± 7.5	67.1 ± 14.4	3.4 ± 0.7	26.3 ± 5.8
70 – 80	11	5 / 6	74.7 ± 4.3 (73 – 80)	161.8 ± 9.8	73.6 ± 10.5	3.7 ± 0.5	30.6 ± 9.0

Fig. 1: Means and standard deviation of the COP path length for each decade during standing with loads in the right hand (white bars), left hand (light grey bars), both hands (dark grey bars) and without holding (CON) external loads (black bars). *Significantly different to CON ($P \leq 0.05$). †Significantly different to 60-69 group in same condition ($P \leq 0.05$). ¥Significantly different to 70-79 years group in same condition ($P \leq 0.05$).
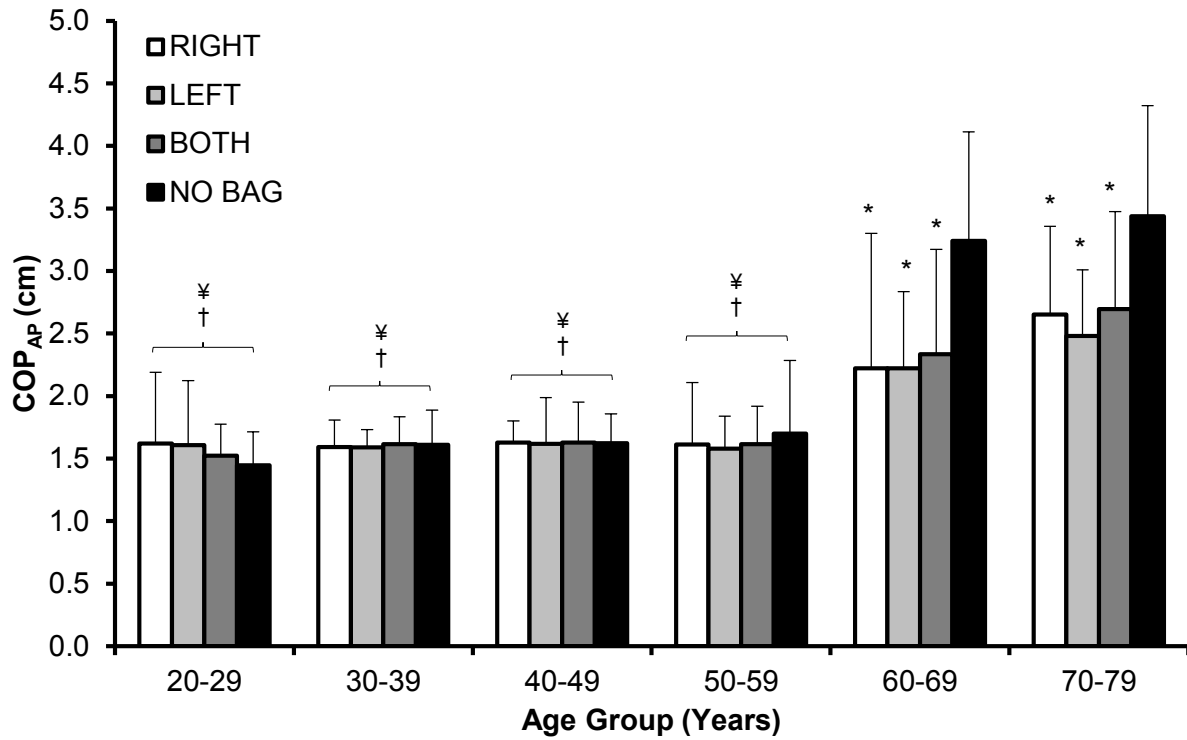
Fig. 2: Means and standard deviation of the anteroposterior COP displacement for each decade during standing with loads in the right hand (white bars), left hand (light grey bars), both hands (dark grey bars) and without holding (CON) external loads (black bars). *Significantly different to CON ($P \leq 0.05$). *Significantly different to CON ($P \leq 0.05$). †Significantly different to 60-69 group in same condition ($P \leq 0.05$). ¥Significantly different to 70-79 years group in same condition ($P \leq 0.05$).
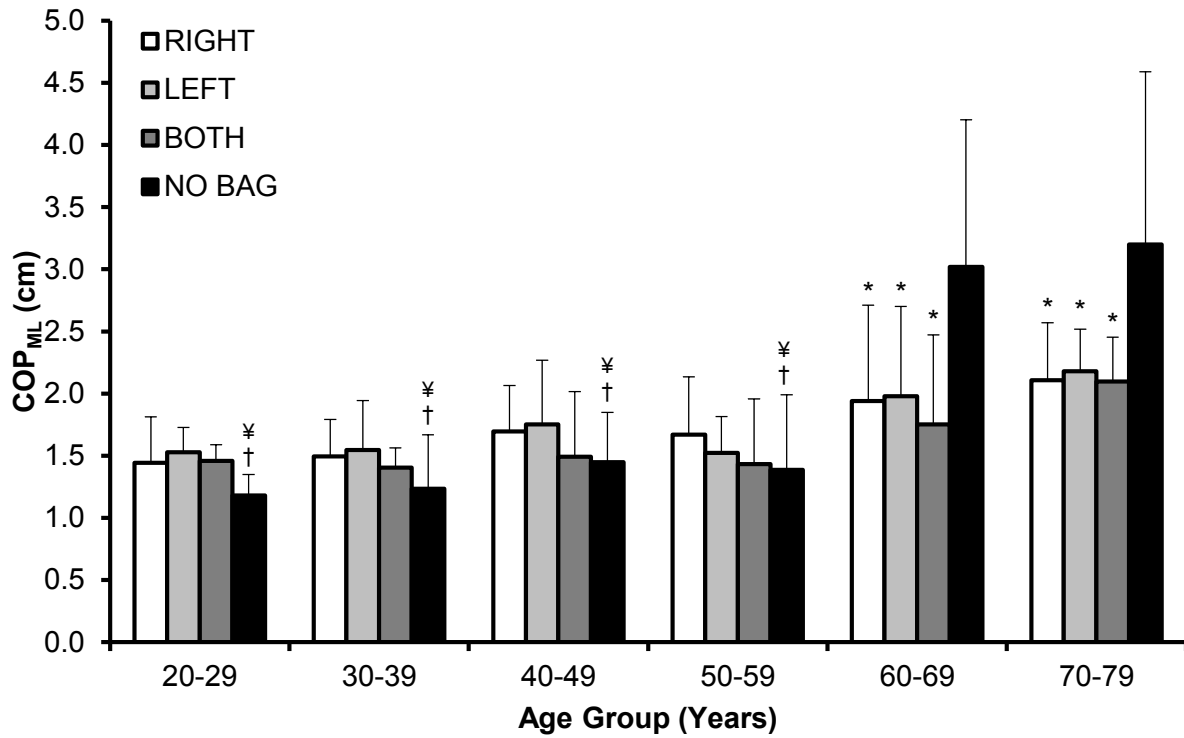
Fig. 3: Means and standard deviation of the mediolateral COP displacement for each decade during standing with load in the right hand (white bars), left hand (light grey bars), both hands (dark grey bars) and without holding (CON) external loads (black bars). *Significantly different to CON ($P \leq 0.05$). *Significantly different to CON ($P \leq 0.05$). †Significantly different to 60-69 group in same condition ($P \leq 0.05$). ¥Significantly different to 70-79 years group in same condition ($P \leq 0.05$).