Functional and Lateral Reach Performance and Standing Balance during Sensory Conflict

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INTRODUCTION

Sensory information from different modalities (visual, vestibular and proprioceptive) should be adequately integrated for optimal standing balance. Otherwise a sensory conflict occurs which interferes with stance. Functional reach (FR) is a test developed by Duncan et al in 1990 [1] which has proven to be a reliable method for falls risk assessment among elderly people [2]. Up to date it has many applications (e.g. assessment of the psychomotor development of children [3, 4], sensorimotor function assessment of patients [5, 6]) and modifications, such as lateral reach (LR) [4,7] and star-test [5]. However, little is known about the influence of sensory conflict on dynamic standing balance during tasks of this type.

AIM

To explore the influence of different sensory conditions: eyes open and sensory conflict (eyes closed or/and head maximally extended) on standing balance during a dynamic task – FR or LR and on task performance as well.

SUBJECTS

Fifteen healthy volunteers (aged 22-34 yrs., mean age 28.47 yrs., SD 3.94 yrs., 6 females) took part in the experiment after signing an informed consent, approved by the local bioethics committee. All subjects were right-handed (verified by modified Annette's test).

EXPERIMENTAL SETUP AND PROCEDURE

Subjects were instructed to reach forward, left and right as far as they could on their own speed. The reaching hands were pronated, in fists. FR was performed with both arms to avoid twisting. No knee flexion or foot lifting were allowed. After a short training, subjects did two trials in four conditions: EO – eyes open, EC – eyes closed (absence of visual information), EO-HE – eyes open, head maximally extended and EC-HE – eyes closed, head maximally extended (adding conflict of vestibular origin). After holding in the farthest position for 3 seconds, an instruction for going back to initial position was given. Reach was measured in mm with a ruler fixed on a wall, the third metacarpal bone was used as a marker. Center-of-pressure (COP) sway was recorded by a pedobarographic platform Tekscan Evolution, provided with Research Software and Sway Analysis Module (SAM) Matscan. Each recording lasted 30 s, the sampling frequency was 30 Hz.

MEASURES AND DATA PROCESSING

The evaluated measures were: maximal reach, COP sway path, medio-lateral (M-L) for FR and anterior-posterior (A-P) COP sway for LR, errors in the return of COP to initial position.

The mean positions of COP before and after the dynamic task, as well as the distance between those two positions (errors in the return) were calculated with a custom-made program in MatLab .

All measures were further evaluated by two-way RM Anova with two factors: vision and head position, and the Student-Newman-Keuls method (SNK) for post hoc testing. We also applied three-way RM Anova for statistical evaluation of the LR measures with reach direction as a third factor. The errors in the COP return were evaluated by t-test versus zero. The measure of statistical significance was chosen to be $p<0.05$.

RESULTS AND DISSCUSSION

Two-way RM Anova for FR length revealed significance for factor head position, but not for vision. For LR both factors were significant. In all cases there was no interaction between the two factors. Post-hoc SNK tests for all three dynamic tasks showed that when vestibular information was distorted (the series with head extended: EO-HE and EC-HE) the lengths of the reach were shorter compared with their analog series with normal head position (EO and EC) (Fig. 1 A-C). Similarly, absence of visual information significantly deteriorated performance in all three standing reaches (Fig. 1 A-C) except in the case of the FR series EC-HE (when both vision and vestibular information were affected) compared to EO-HE (Fig. 1 A). The results suggest that sensory conflict significantly shortened the standing reach distance, especially in the case where both visual and vestibular modalities were affected (EC-HE). Our results support the findings of Deshmukh et al (2011)[4] that reach distance of FR is greater than that of LR. They also correspond to the longer COP sway path during the FR series compared to the LR ones (Fig. 2 A-C). We did not find any significant differences regarding reach distances between LR made with dominant vs. non-dominant hand (three-way RM Anova).

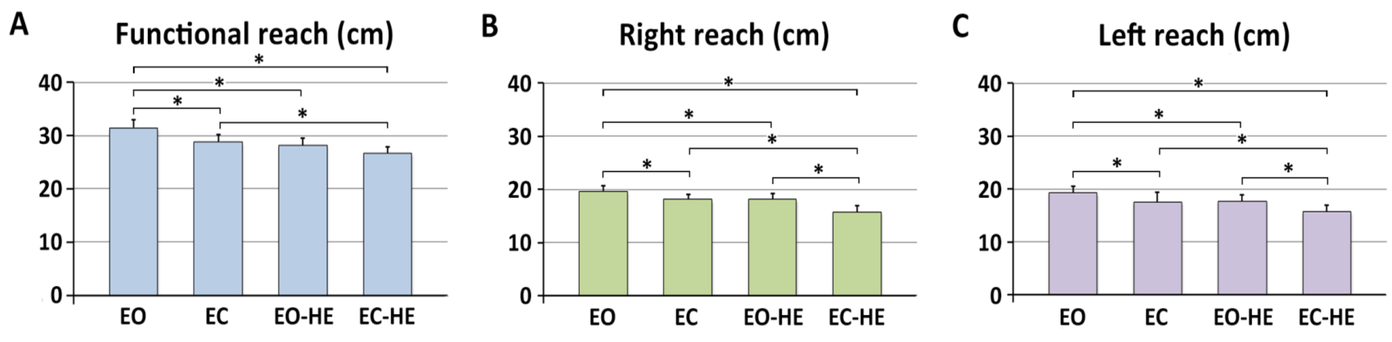

Fig. 1. *Mean and standard error of mean (SEM) lengths of maximal reach. Significant differences ($p<0.05$, Two-way RM Anova, post hoc analysis - SNK) between series are marked with asterisks (**A** - functional reach; **B** - right reach; **C** - left reach).*

Two-way RM Anova for the COP sway path revealed that both factors vision and head position were significant without interaction between them for all three standing reaches. Post hoc SNK tests for all three dynamic tasks showed that in absence of visual information (in the series with eyes closed: EC and EC-HE) the COP sway path was longer compared to their analog series with eyes open (EO and EO-HE) (Fig. 2 A-C). Similarly, distorted vestibular information significantly prolongs the COP path in all three standing reaches (Fig. 2 A-C) except in the case of FR when only vestibular information was affected - during EO-HE (compared series - FR: EO-HE vs. EO) (Fig. 2 A). The results suggest that sensory conflict significantly increased body sway, especially in the case where both visual and vestibular modalities were affected (EC-HE), which corresponds with the shortest reach performance in these series (Fig. 1 A-C). A reweighting in favor of proprioception is very possible in the EC-HE series. It can also explain the lack of correspondence between the increased COP sway path and task performance in the FR series EC-HE.(Fig.1 A) but not in the LR series. The longer COP sway path in the FR series compared to the LR series (Fig. 2 A-C) supports the above mentioned findings that the reach distance of FR is greater than that of LR (Fig. 1 A-C). We did not find significant differences regarding the COP sway path between left and right reach (three-way RM Anova).

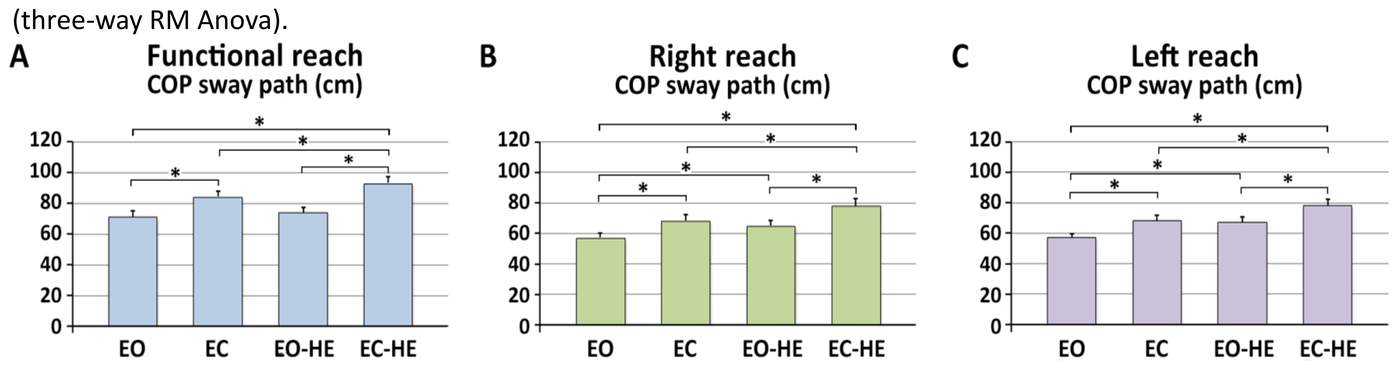

Fig. 2. *Mean and standard error of mean (SEM) of the sway path of the center of pressure (COP) during trials. Significant differences ($p<0.05$, Two-way RM Anova, post hoc analysis - SNK) between series are marked with asterisks (**A** - functional reach; **B** - right reach; **C** - left reach).*

Changes in the COP sway in the perpendicular direction of the main direction of the tasks are shown on Fig. 3 A-C. Two way Anova revealed that only factor vision is significant for the FR with an increased M-L COP sway during the eyes-closed series compared to their corresponding eyes-open series (Fig. 3 A). The results of the A-P COP sway during left reach were similar (Fig. 3 B) while during right reach both factors vision and head position were significant, leading to increased COP sway in the A-P direction (Fig. 3 C). No statistically significant interaction between the two factors was found in all cases. We did not find significant differences in the M-L COP sway between left and right reach (three-way RM Anova).

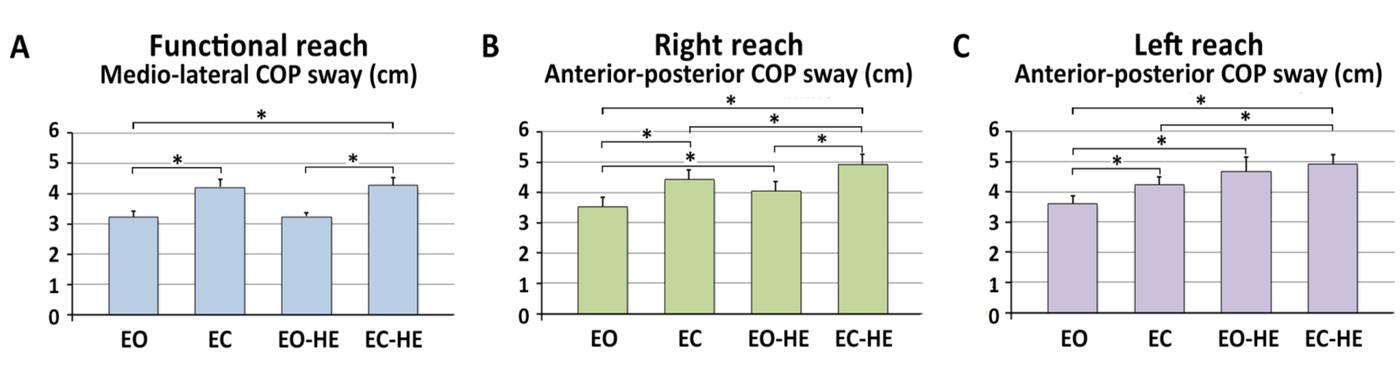

Fig. 3. *Mean and standard error of mean (SEM) of the anterior-posterior or medio-lateral sway of the center of pressure (COP) during trials. Significant differences ($p<0.05$, Two-way RM Anova, post hoc analysis - SNK) between series are marked with asterisks (**A** - functional reach; **B** - right reach; **C** - left reach).*

Standing reach itself occupied about one third of the trial (Fig. 4). After the reach the COP sway gradually diminished to pre-reach values (regaining standing balance). However, we observed a statistically significant overshoot of the COP return position vs. its initial one (Fig. 4, 5). This finding suggests that postural alignment did not recover after the reach until the end of the recording. Our results are in line with Centomo et al. 2007 [5] with the difference that their subjects had bigger problems in regaining their balance after reach, most probably because they were about 20 years older than our subjects.

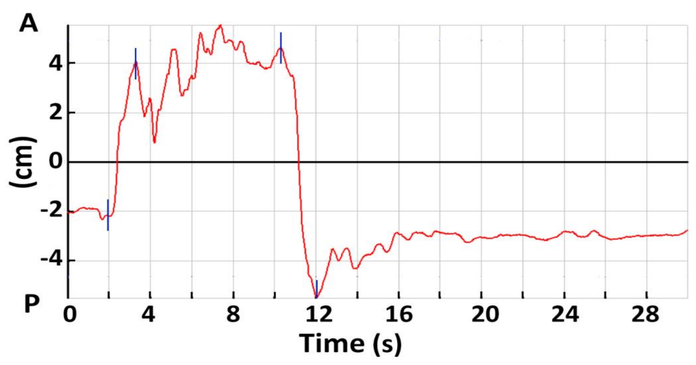

Fig. 4. *Anterior (A) and posterior (P) excursions of COP in cm during one trial of FR, EO. Vertical blue lines indicate: start and end of the forward displacement of COP, start and end of the backward displacement of COP.*

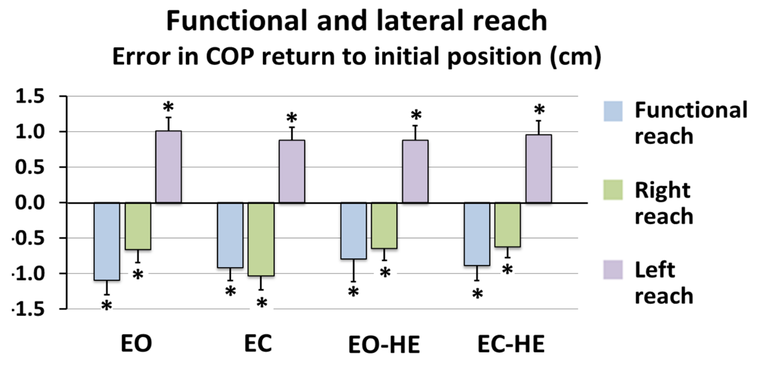

Fig. 5. *Mean and standard error of mean (SEM) of the difference in the mean positions of the center of pressure (COP) during functional and lateral reach. Significant differences ($p<0.05$, paired t-test) between each sample and 0 are marked with asterisks.*

CONCLUSIONS

Dynamic standing balance and reaching task performance are vision- and vestibular-dependent and they deteriorate in the presence of sensory conflict affecting these modalities. This deterioration is expressed the most when both modalities are affected. The overshoot in the after-reach COP return to initial position suggests a deficit in the regaining of postural alignment which is prospective for further studies. Both functional and lateral reach test in the sensory conflict context can serve as sensibilized variants for early risk of fall detection and prevention.

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