SENSITIVITY OF BODY SWAY PARAMETERS DURING QUIET STANDING TO MANIPULATION OF SUPPORT SURFACE SIZE

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Introduction

For the purpose of describing the ability to maintain a balanced body posture, various body sway (BS) parameters are used in clinical, sports and research practices [1]. The selection of suitable BS parameters depends on the methods to be used, as well as on the stationary or dynamic nature of the balancing task [4,6,8]. Manipulating various biomechanical factors that affect BS, creates an opportunity for a more analytical insight into clinical balance testing and goal directed training [2,9]. The support surface size (SSS), mathematically defined as the convex hull of the contact surface, is most commonly modified. The aim of this study was to evaluate the sensitivity of those COP parameters which proved to have the highest repeatability [7]. For this purpose a systematic modification of the SSS by changing foot positions was used. As an outcome, based on the acquired results, some indications for practical use are proposed.

Methods

- 29 subjects (13 ♂ and 16 ♀, age 26.3 ± 4.7 years),
- the subjects' task was to maintain a balanced position in each of five foot placements, which are graphically described in (*Figure 1*).

During quite stance the following parameters were monitored (Sarabon et al., 2010b):

- the total distance performed by the center of pressure (S_Σ),
- the COP distance covered in the m-l and a-p direction (S_{m-l} and S_{a-p}, respectively),
- the maximum amplitude in the m-l and a-p direction (A_{m-l} and A_{a-p}, respectively),
- the total frequency of oscillation in the m-l and a-p directions (F_Σ),
- the frequency of oscillation in the m-l and a-p direction (F_{m-l} and F_{a-p}, respectively).

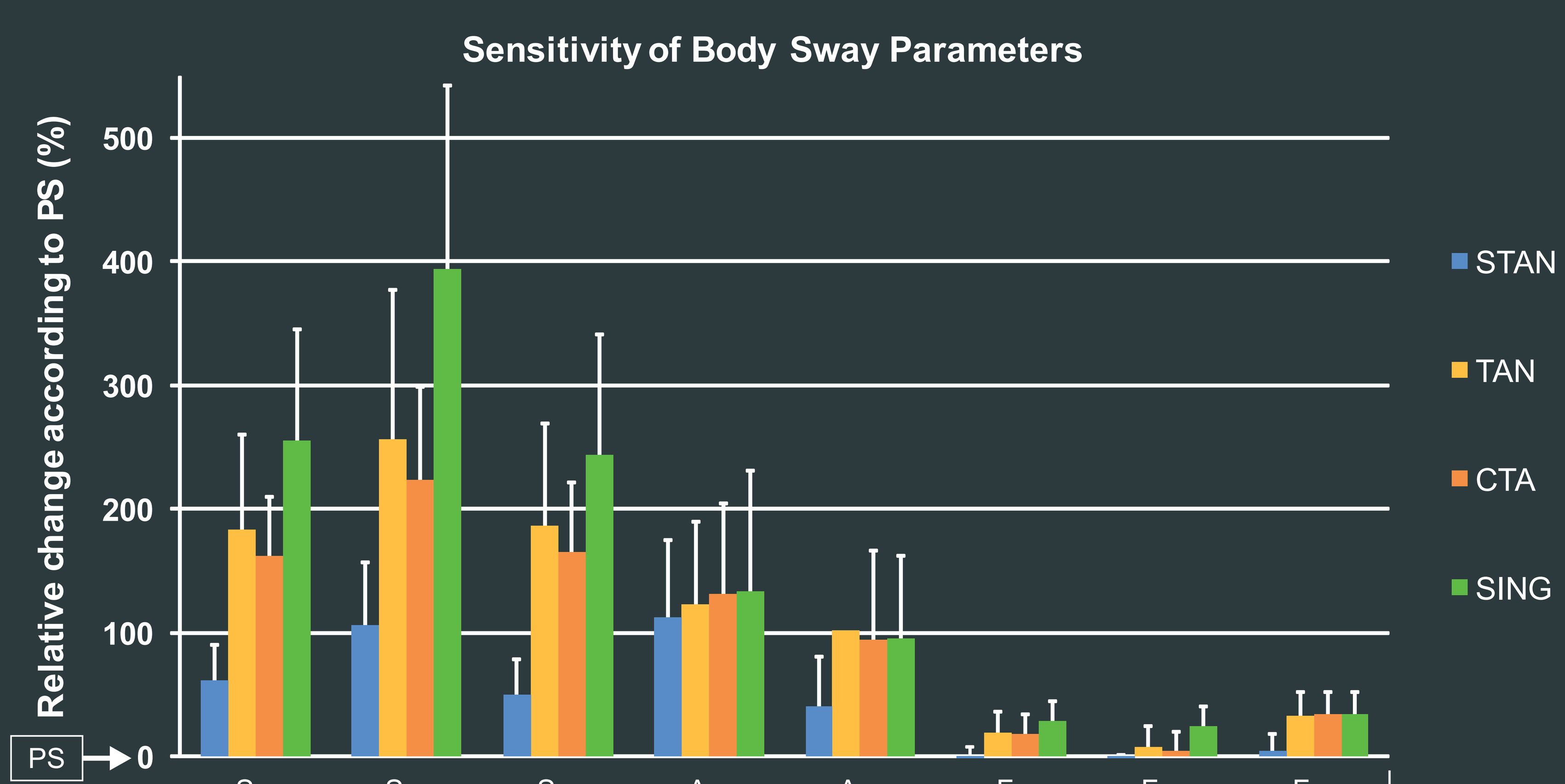
Statistics:

- Intra-class correlation coefficients (ICC) and their confidence limit intervals to check for repeatability.
- Means of two-way repeated measures analysis of variance (RANOVA) to test the differences among various foot placements.
- Paired T-tests with Bonfferoni corrections for multiple comparisons were applied post hoc.
- The Pearson correlation coefficient (r) was used to test the correlations between S_Σ, S_{m-l}, and S_{a-p}.

Figure 1: The five different foot positions used: (a) PS, (b) SET, (c) TAN, (d) CTA, and (e) SL. The leg dominance is marked by D (dominant leg) and ND (non-dominant leg). Note that the m-l dimension in PS (a) equals that of the hip-width.

Results

- All eight measured COP parameters proved to be responsive to the changes in SSS.
- The biggest changes and differences among individual balance tasks were observed in parameters S_Σ, S_{m-l} and S_{a-p}.
- The biggest was the change in S_{m-l} in SL.
- Parameters A_{m-l}, A_{a-p}, F_Σ, F_{m-l}, and F_{a-p} were responsive to a slightly lower degree, but all of them reflected a change according to the PS.
- Statistically significant differences ($p < 0.05$) were observed in S_Σ, S_{m-l}, and S_{a-p} pair-wise comparisons with the exception of TAN:CTA and TAN:SL.
- The weakest intra-session repeatability (ICC) in all conditions was observed for A_{a-p}. A_{m-l} also proved to have poor repeatability (ICC), while all other parameters exhibited good repeatability (majority of ICC values above 0.80), in particular for S_Σ, S_{m-l}, and S_{a-p}.



S_Σ	S_{m-l}	S_{a-p}	A_{m-l}	A_{a-p}	F_Σ	F_{m-l}	F_{a-p}	
**	**	**	**	**	*	*	**	RANOVA (5×)
*	*	**	**	*	n.s.	n.s.	n.s.	PS:SET
**	**	**	**	**	n.s.	n.s.	n.s.	PS:TAN
**	**	**	**	**	n.s.	n.s.	n.s.	PS:CTA
**	**	**	**	**	n.s.	n.s.	*	PS:SL
**	**	**	n.s.	n.s.	*	n.s.	n.s.	SET:TAN
**	**	*	n.s.	n.s.	n.s.	n.s.	n.s.	SET:CTA
**	**	*	n.s.	n.s.	*	*	n.s.	SET:SL
n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	TAN:CTA
*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	TAN:SL
*	*	*	n.s.	n.s.	n.s.	n.s.	n.s.	CTA:SL

Figure 2: Relative changes in individual COP parameters as a result of SSS manipulation. Vertical bars (average + standard deviations) represent values of COP parameters relative to the PS values. Statistical significance is indicated (* for $p < 0.05$, ** for $p < 0.01$ and n.s. for $p \geq 0.05$) in the table below for RANOVA (first row) and T-tests (the lower rows from the second on).

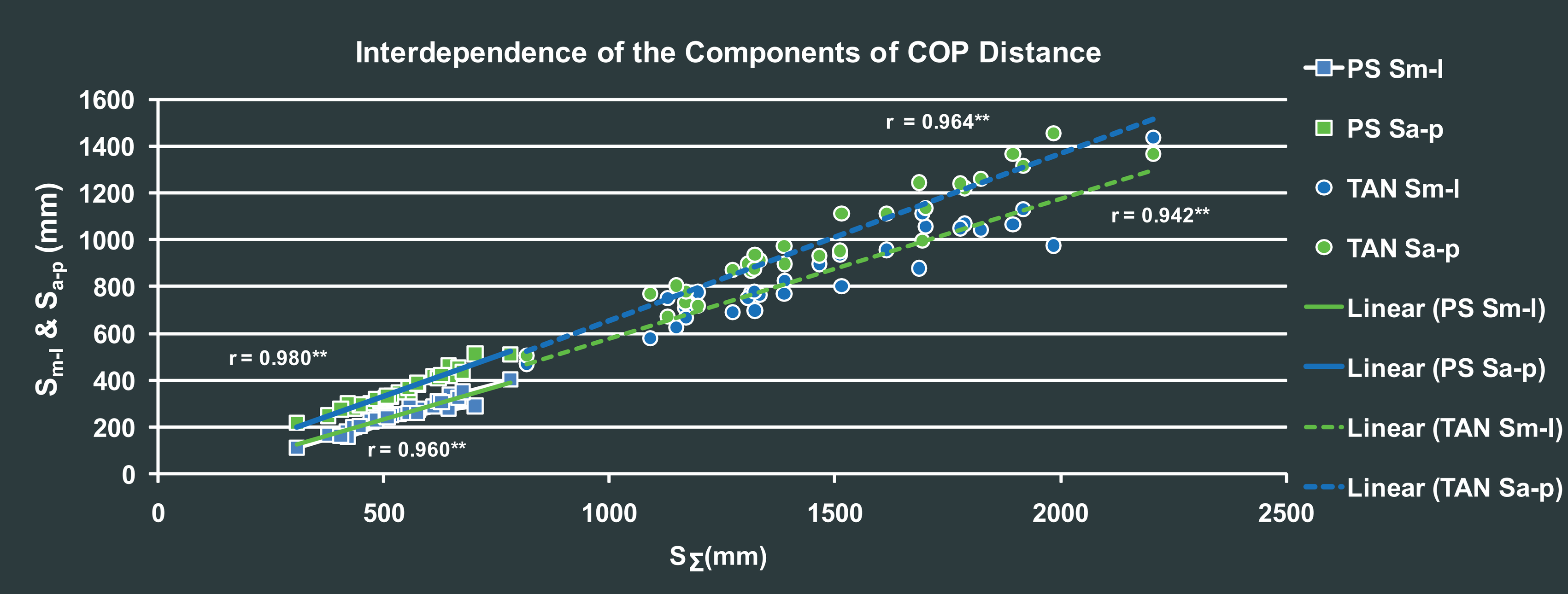


Figure 3: Relationship between S_Σ and S_{m-l} or S_Σ and S_{a-p} for SL and TAN. Pearson correlation coefficients (r) and levels of statistical significance are indicated (** for $p < 0.01$).

Correlations among S_Σ:S_{m-l}, S_Σ:S_{a-p} and S_{m-l}:S_{a-p} for all balance tasks were high (over 0.9 for S_Σ:S_{m-l}, S_Σ:S_{a-p}, $p < 0.05$ and over 0.76 for S_{m-l}:S_{a-p}, $p < 0.05$).

Discussion

The effects of changing SSS are routinely assessed in clinical practice to identify possible balance deficits [3]. Differences due to changed SSS must be considered by physicians before the specific effects of pathology or exercise are interpreted. As seen in this study, maximal amplitudes and distance parameters of the COP, when using a single force plate, proved to be highly sensitive to small changes in SSS. This suggests that SSS has a major effect on BS parameters tested on healthy subjects.

Our results showed that when the support surface is reduced, the S_Σ, S_{a-p}, and S_{a-p} increase. We can speculate that this happens because of the need for a longer lever arm, in order to ensure the proper counter torque for the COM corrections, when the SSS is small.

The results of the current study and those of our previous one can conclude the following: (i) the selected amplitude, frequency, and cumulative distance parameters of the COP movement in the quiet stance tasks are repeatable measures of balance, (ii) the method is sufficiently sensitive for detecting inter-individual differences, (iii) from these parameters, amplitudes of oscillation, resulting also in cumulative distance parameters, are the most sensitive to SSS manipulations, and (iv) direction specific changes in the SSS cause direction unspecific changes in COP movement.

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