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1 **Title:**

2 Frequency coherence analysis of postural balance in able-bodied and in non-treated
3 adolescent idiopathic scoliotic girls.

4

5 **Author names and affiliations:**

6 Sébastien Leteneur^{a,b,c}, Sylvain Crémoux^{a,b,c}, Paul Allard^{d,e}, Émilie M. Simoneau^{a,b,c},
7 Nader Farahpour^f and Franck Barbier^{a,b,c}

8

9 ^aUniv Lille Nord de France, F-59000 Lille, France

10 ^bUPHF, LAMIH, F-59313 Valenciennes, France

11 ^cCNRS, UMR 8201, F-59313 Valenciennes, France

12 ^dDepartment of Kinesiology, University of Montreal, C.P. 6128, Succursale Centre-ville,
13 Montreal, Quebec H3C 3J7, Canada

14 ^eHuman Movement Laboratory, Research Center, Sainte-Justine Hospital, 3175 Côte-Ste-
15 Catherine, Montreal, Quebec, Canada H3T 1C5

16 ^fDepartment of Physical Education and Sport Science, University Bu-Ali Sina, Hamadan,
17 Iran

18

19 **Corresponding author:**

20 Sébastien Leteneur, LAMIH, Université Polytechnique Hauts-de-France, Campus du
21 Mont Houy, 59313 Valenciennes Cedex 09, France

22 Email: sebastien.leteneur@uphf.fr

23

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28 **Frequency coherence analysis of postural balance in able-bodied and in non-treated**
29 **adolescent idiopathic scoliotic girls**

30

31 **Abstract**

32 **Background:** This study test if the frequency coherence calculated for the overall, low
33 and high frequency bandwidths of the center of pressure excursions and free-moment
34 calculated during standing balance are similar between scoliotic and non-scoliotic girls
35 and if the coherence values within each frequency band are comparable for a given group
36 of girls.

37 **Methods:** Twenty-nine girls with adolescent idiopathic scoliosis formed the scoliotic
38 group and 22 able-bodied girls formed the non-scoliotic group. Each girl maintained a
39 quiet upright stance on a force plate. Three trials were performed at a sampling frequency
40 of 64 Hz for 64s. Mean antero-posterior, medio-lateral center of pressure positions and
41 free-moment were measured and their frequency content calculated. The magnitude of
42 the coherence was calculated for each signal pairs for three frequency ranges.

43 **Results:** The magnitude of the medio-lateral center of pressure/free-moment coherence in
44 the low and high frequency bands was significantly different between the groups. Within
45 each group, the magnitude of the medio-lateral center of pressure/free-moment coherence
46 was significantly higher than the other two coherence pairs at low frequencies ($P<0.001$).
47 Factor analysis revealed that able-bodied girls exhibited a mixed standing balance
48 modality consisting of posture (center of pressure) and proprioceptive information (free-

49 moment). Scoliotic girls adopted an adaptive modality mostly based on proprioception
50 information to maintain their standing balance.

51 **Interpretation:** Scoliotic girls systematically depend on the free-moment to modulate
52 their antero-posterior center of pressure displacements. These results suggest a postural
53 reeducation program aimed at improving proprioception while repositioning the mean
54 center of pressure by postural corrections.

55 **Key Words:** scoliosis; posture; proprioception.

56 **Introduction**

57 The quality of upright posture and standing balance is usually assessed by the center of
58 pressure (CoP) position and its displacements. The mean antero-posterior (AP) and
59 medio-lateral (ML) positions of the CoP are associated with body posture (Winter, 1995)
60 whereas the free moment acting at the CoP is representative of upper limbs and trunk
61 control around the vertical axis to maintain standing balance (Beaulieu et al., 2009;
62 Dalleau et al., 2007) Changes in sensory, task, or perturbation conditions affect the CoP
63 excursions (Creath et al., 2005) requiring an effort from the free moment for postural
64 stabilization (Esposti et al., 2010). To our knowledge, no one has studied the
65 relationships between the free moment and CoP displacements in the frequency domain
66 during quiet standing of subjects with scoliosis. Evaluating the spectral relationship
67 between postural parameters such as the CoP positions and proprioceptive information
68 gained through the free moment in subjects with scoliosis could orient clinicians to favor
69 either or both balance modalities in the physical reeducation program and in adapting
70 body braces to prevent scoliosis progression.

71

72 Even though spectral analysis was used to evaluate quiet standing (Creath et al., 2005;
73 Zhang et al., 2007), only Hay and Wachowiak (Hay and Wachowiak, 2017) applied this
74 method to assess the interaction between ML and AP centers of pressure and the free
75 moment. Their spectral analysis was performed on data collected from a group of able-
76 bodied adults comprising equally of women and men. They calculated the interaction or
77 frequency coherence between signal pairs comprising of the combination of the ML and
78 AP centers of pressure and the free moment. High coherence values between the CoP

79 displacements and the free moment in different frequency bandwidths suggested
80 adaptations from different parts of the body to regulate upright balance posture.
81
82 It is reasonable to assume that a similar approach could be applied to elucidate complex
83 interactions especially in populations such as adolescents with idiopathic scoliosis. The
84 three-dimensional deformation of the spine (Sahlstrand et al., 1978), pelvis distortion
85 (Begon et al., 2015) and body morphology (Allard et al., 2004) are associated with an
86 increased displacement in center of pressure towards the ankle explaining in part their
87 hypokyphotic posture. These morphologic and postural changes lead to standing
88 imbalance (Nault et al., 2002) requiring a corrective torque applied by the trunk and other
89 body segments limbs to counteract standing balance destabilization (Dalleau et al., 2007).
90 Proprioceptive information induces a corrective torque generated through the action of
91 active feedback-control mechanisms (Simoneau et al., 2006a) by the free moment.
92
93 Hay and Wachowiak (Hay and Wachowiak, 2017) estimated the degree of the interaction
94 between the CoP and free moment signal pairs by calculating the mean squared
95 coherence as a function of frequency. Then they calculated the confidence interval of
96 each signal to identify the frequencies where statistical differences were present.
97 Following this confidence interval analysis, results were reported to occur at two
98 frequency ranges, namely at low frequencies below 0.5 Hz and at higher frequencies
99 ranging from 0.5 Hz to 1.5 Hz. Based on this study, our approach was to perform a
100 coherence analysis on signals taken at different predetermined frequency bandwidths,
101 namely overall and below and above 0.5 Hz. This has the advantage of focusing the

102 coherence analysis in specific frequency bandwidths rather than identifying them once
103 the coherence analysis is performed.

104

105 The objectives of this work were to test if the coherence calculated for the overall, low
106 and high frequency bandwidths between the CoP excursion and its corresponding free
107 moment observed during standing balance of scoliotic and non-scoliotic girls are similar
108 and if the coherence values within each frequency band are comparable within each
109 group of girls. Furthermore, factor analysis was used to identify the frequency coherence
110 variables which best identify balance modalities in the scoliotic and non-scoliotic girl
111 data sets. This approach would allow to evaluate both proprioception and postural
112 corrections that can be proposed in the rehabilitation of scoliotic patients.

113

114

115 **Methods**

116 A group of 29 girls diagnosed with adolescent idiopathic scoliosis according to the
117 criteria defined by Bunnel (Bunnel, 1986) participated to this study. Their mean age was
118 12.7 years (SD 1.8 years) while their height and weight were 153.7 cm (SD 10.7 cm) and
119 43.0 kg (SD 9.5 kg), respectively. The average Cobb angle was 27.4° (SD 11.3°) and
120 ranged between 11° and 49° and all curves were to the right. No patient was under active
121 treatment at the time of this study. A group of 22 able-bodied girls formed the non-
122 scoliotic group. None had any form of scoliosis and all were in general good health. A
123 subject with a limb length discrepancy of more than 1 cm, wearing a foot orthosis or who
124 displayed any signs of postural, orthopedic or neurological disorders was excluded from

125 the study. This group was comparable in age (13.1 years, SD 1.4 years, $P=0.285$), height
126 (156.8 cm, SD 6.9 cm, $P=0.204$) and weight (45.9 kg, SD 7.7 kg, $P=0.233$) to the
127 scoliotic group. All the girls and their parents signed the informed consent form approved
128 by the hospital ethics committee.

129

130 The quality of quiet standing was determined by having each girl maintain a quiet upright
131 stance on an AMTI force plate (Model OR6-5, Newton, MA, USA) with the feet barefoot
132 and positioned with the heels spaced by 23 cm and the toes pointing externally by 15°
133 (McIlroy and Maki, 1997) Each girl focused their eyesight on a target placed at 1.2 m
134 ahead and located at eye level (Allard et al., 2004; Dalleau et al., 2011) with the arms
135 parallel to the trunk. Three trials were performed at a sampling frequency of 64 Hz for a
136 duration of 64 s (Nault et al., 2002).

137

138 From the forces and moments measured by the force plate, the antero-posterior (AP) and
139 medio-lateral (ML) center of pressure (CoP) positions were calculated with respect to the
140 center of the force plate at each instant of a trial. The free moment (T_z) is the moment
141 acting at the CoP along the vertical axis. It is calculated from the vertical moment and the
142 moments resulting from the antero-posterior and medio-lateral forces acting at the origin
143 of the force plate (Dalleau et al., 2007) The mean antero-posterior (CoP_{AP}) and medio-
144 lateral (CoP_{ML}) center of pressure positions were calculated for each subject from their
145 respective trials.

146

147 The CoP excursion in the AP and ML directions and the corresponding free moments
148 were processed as individual signals as shown in Fig 1 and 2. Each CoP_{AP}, CoP_{ML} and T_Z
149 signals were filtered with a zero-lag 4th order Butterworth low-pass filter having a 20 Hz
150 cut-off frequency (Fig. 1 A to C). Then each signal was divided into six 10s epochs. This
151 was performed for the three trials totaling in 18 epochs per subject per signal type
152 (CoP_{AP}, CoP_{ML} and T_Z). Afterwards, the mean epoched signal was calculated and
153 removed from each signal to obtain a zero-centered epoched CoP_{AP}, CoP_{ML} and T_Z
154 signals (Fig. 1 D to F).

155

156 PLEASE INSERT FIG 1 ABOUT HERE

157

158 The wavelet auto-spectrum of each zero-centered epoched signal (Fig. 2A to C) and the
159 wavelet cross-spectrum between each zero-centered epoched signal (Fig. 2 D to F) were
160 obtained with a Morlet wavelet transform (Gasq et al., 2015) yielding a 0.16 Hz to 8.00
161 Hz frequency band in 0.05 Hz steps. This frequency bandwidth corresponds to the overall
162 frequency range of the whole signal. The wavelet magnitude-squared coherences,
163 $R_{X,Y}^2(\omega, u)$, are shown in Fig. 2 G to I. The wavelet cross-spectrum normalized by the
164 wavelet auto-spectrum of each signal, was obtained by

165

$$R_{X,Y}^2(\omega, u) = \frac{|S_{X,Y}(\omega, u)|^2}{S_X(\omega, u)S_Y(\omega, u)}$$

166 where $S_{X,Y}(\omega, u)$ is the wavelet cross-spectrum between X and Y signals (COP_{AP}, COP_{ML}
167 and T_Z signals) and $S_X(\omega, u)$ and $S_Y(\omega, u)$ are the wavelet auto-spectrum of each X and Y
168 signals at frequency ω and time u .

169

PLEASE INSERT FIG 2 ABOUT HERE

170

171

172 To properly quantify the magnitude of the $\text{CoP}_{\text{AP}}\text{-CoP}_{\text{ML}}$, $\text{CoP}_{\text{AP}}\text{-Tz}$ and $\text{CoP}_{\text{ML}}\text{-Tz}$

173 coherences, values were averaged only where significant correlations between two

174 signals were detected as significant on the wavelet cross-spectrum (Bigot et al., 2011).

175 For each signal pairs, the magnitude of the coherence was averaged over the entire time

176 period for three frequency bands: overall frequency band (0.16-8.00 Hz), low frequency

177 band (0.16-0.50 Hz) and high frequency band (0.50-8.00 Hz) respectively. The 0.5 Hz

178 demarcation frequency was based on the results reported by Hay and Wachowiak (Hay

179 and Wachowiak, 2017).

180

181 Independent one-way ANOVA was performed on the mean CoP positions and the 9

182 coherence values (3 pairs and 3 frequencies) to compare the able-bodied and the scoliotic

183 groups. Another one-way ANOVA was performed to compare the magnitude of the

184 coherence values between each signal pairs, $\text{CoP}_{\text{AP}}\text{-CoP}_{\text{ML}}$, $\text{CoP}_{\text{AP}}\text{-Tz}$ and $\text{CoP}_{\text{ML}}\text{-Tz}$

185 independently for each frequency band and subject group. A Bonferroni correction

186 procedure was applied to control Type 1 error by adjusting the P values in the analysis

187 (Holland and Copenhaver, 1988) and a P value of 0.05 or smaller was considered

188 statistically significant. Finally, a factor analysis was carried out for each subject to

189 estimate the relative contribution of the coherence relationships. Factors with an

190 eigenvalue greater than 1 and variables with a factor loading of 0.7 or above were

191 considered as statistically significant (Sadeghi, 2000).

192

193 **Results**

194 Table 1 presents the average values of the mean CoP and those of the coherence values
195 for the three comparisons pairs for each of the three frequency bands. Though the mean
196 medio-lateral CoP of the scoliotic group was more centered than that of the able-bodied
197 subjects, it was not statistically significant. This could be due in part to its large standard
198 deviation. However, the scoliotic girls maintained a more rearward CoP position than the
199 non-scoliotic girls by 11.6 mm. Only the magnitudes of the CoP_{ML-TZ} coherence were
200 significantly different in the low and high frequency bands. It appears that the scoliotic
201 group displayed a greater dependence on free moment at low frequencies and lesser one
202 at higher frequencies.

203

204 PLEASE INSERT TABLE 1 ABOUT HERE

205

206 When comparing the magnitude coherence pairs at different frequency bands but within
207 each subject group, only the magnitude of the CoP_{AP-TZ} coherence was significantly
208 higher than the magnitude of the other two coherence pairs at low frequencies ($P < 0.001$),
209 as shown in Fig. 3. The overall frequency and the high frequency bands do not present
210 any statistical difference.

211

212 PLEASE INSERT FIG 3 ABOUT HERE

213

214 Factor analysis revealed that only three principal components (PC) were necessary to
215 explain 83% and 80% of the variance in the able-bodied and scoliotic girls respectively.

216 The frequency coherence pairs of the able-bodied group are well distributed among the
217 three PCs as shown in Table 2. It seems that this group favored a mixed standing balance
218 modality of posture and proprioceptive information. However, the first two PCs included
219 coherence pairs in the overall and high frequency bandwidths whereas the coherences
220 calculated in the low band frequency range were in the third PC.

221

222 The scoliotic girls adopted an adaptive modality based on the free-moment to maintain
223 their standing balance. Regardless of frequency band, they principally relied (first PC) on
224 the interaction between the free moment and the CoP_{AP} to preserve their standing
225 balance, implying a greater dependence on proprioception information. All the coherence
226 CoP pairs were grouped in the second PC emphasizing a postural balance modality. The
227 medio-lateral CoP dependence on the free moment occurred in the third PC.

228

229

PLEASE INSERT TABLE 2 ABOUT HERE

230

231 **Discussion**

232 Standing imbalance in adolescent idiopathic scoliosis girls has been well documented
233 (Sahlstrand et al., 1978). Both the position of the CoP characterizing standing body
234 posture and its linear displacements have been associated with axial torsion of the spine
235 and trunk (Gauchard et al., 2001) and perturbed proprioception (Simoneau et al., 2006b).
236 These observations reflect an imbalance around the vertical axis characterized by the free
237 moment (Dalleau et al., 2007). The relationships between the CoP linear excursion and
238 the free moment were documented by Hay and Wachowiak (Hay and Wachowiak, 2017)

239 within the range of important frequencies in a mixed group of able-bodied adult women
240 and men but they remain unknown in symptomatic populations.

241

242 Though the scoliotic group of this study maintained a centered mean medio-lateral CoP
243 position similar to the non-scoliotic girls, they accomplished it with more difficulty. The
244 CoP_{ML} standard deviation was nearly twice as large as that of the able-bodied group.
245 Concomitantly, the magnitude of their CoP_{ML}-T_Z coherence was greater than that of the
246 able-bodied subjects at low frequencies. This reflects a greater use of their hips or trunk
247 rotations to maintain their center of mass over the body midline position and explains in
248 part the large CoP_{ML} standard deviation. This is in agreement with Gage et al. (Gage et
249 al., 2004) and Shiratoni and Aruin (Shiratori and Aruin, 2004) who reported that postural
250 control in standing can be achieved by the whole body moving in a single block or
251 through individual body segment movements to stabilize the joints. Interestingly, smaller
252 mean coherence values in the high frequency band suggest a greater independence
253 between the CoP excursion and the free moment to maintain quiet standing balance in the
254 scoliotic group. At higher frequencies the proprioceptive modality succeeds the postural
255 one (Beaulieu et al., 2009; Dalleau et al., 2007; Hay and Wachowiak, 2017; Simoneau et
256 al., 2006b).

257

258 For each group, the magnitude of the coherence between CoP_{AP}, CoP_{ML}, and T_Z was
259 independently compared in the three different frequency ranges. The hypothesis was to
260 ascertain whether a postural or a proprioception modality dominates at a particular
261 frequency range. In both groups, a significantly higher magnitude of coherence was

262 found between the free moment and the antero-posterior displacements in comparison to
263 the other coherence pairs at low frequencies. This suggests an ankle balance strategy
264 necessitating proprioception control from the free moment to maintain standing balance
265 (Hay and Wachowiak, 2017). A greater free moment range and Root Mean Square as
266 well as statistically moderate correlations between the free moment values and the CoP_{AP}
267 displacements were reported in scoliotic girls by Dalleau et al. (Dalleau et al., 2007). The
268 frequency domain analysis not only confirms a high $CoP_{AP}-T_Z$ coherence in scoliotic girls
269 but also in non-scoliotic individuals. Hay and Wachowiak (Hay and Wachowiak, 2017)
270 have suggested that CoP_{AP} and T_Z were strongly correlated at low frequencies in a mixed
271 adult population. Our study confirms this observation in both scoliotic and non-scoliotic
272 girls though no statistical difference was found among the coherence values in the high
273 frequency range. The latter observation could be an age-related factor.

274

275 The main difference between both groups lies in the magnitude of $CoP_{ML}-T_Z$ coherence at
276 low and high frequencies. Medio-lateral imbalance has been well documented in scoliotic
277 girls and relatively absent in able-bodied populations (Bruyneel et al., 2008). The need
278 for rearfoot control at heel-strike during gait confirms of medio-lateral function in
279 prosthetic foot designs (Allard et al., 1992; Allard et al., 1995).

280

281 Following a factor analysis, it appears that the non-scoliotic girls displayed a mixed
282 balance modality involving proprioception ($CoP_{AP}-T_Z$) and posture ($CoP_{AP}-CoP_{ML}$)
283 information distributed among the first two PC. This is not surprising since such a group
284 has no musculoskeletal ailments or neurologic disorders to exacerbate proprioception

285 regulation. In scoliotic girls, the first PC grouped all the $\text{CoP}_{\text{AP-TZ}}$ coherences regardless
286 of the frequency band. Postural modality only appears in the second PC with high
287 eigenvalues for coherence between $\text{CoP}_{\text{AP}}-\text{CoP}_{\text{ML}}$. This is not surprising since scoliotic
288 girls assume a 12 mm mean rearward antero-posterior CoP position than the non-scoliotic
289 group exacerbating their balance. Furthermore, it was reported that scoliosis interferes
290 with the mechanisms responsible for sensory reweighting during balance control
291 (Simoneau et al., 2006a). Proprioception was perturbed at the ankle by a vibratory
292 stimulus that deprives subjects from relevant ankle proprioceptive information produced
293 by body sway. The vibrators were activated (sensory deprivation interval) and
294 deactivated (sensory reintegrated interval) while subjects stood on a force plate. It was
295 concluded that scoliotic adolescents have difficulty in dynamically adjusting the weight
296 of the various sensory inputs to tailor the balance control commands following a brief
297 period of sensory deprivation. Balance control dysfunction in scoliotic girls could be the
298 consequence of the three-dimensional deviation of the spine (Nault et al., 2002) and
299 changes in the orientation of various segments (Zabjek et al., 2005), and neuromuscular
300 disfunction (Farahpour et al., 2014; Dobosiewicz, 1997). These observations support the
301 role and the importance of the free moment relationship with the antero-posterior CoP
302 displacements in scoliotic subjects.

303

304 Physical conservative treatments of scoliosis are based on manual therapy techniques
305 (Lotan and Kalichman, 2018; Th eroux et al., 2017), exercise-based physical therapy
306 (Kalichman et al., 2016) or physical activity (Green et al., 2009). Generally, physical
307 treatments aimed to improve either posture (Penha et al., 2017) or proprioception

308 (Pialasse et al., 2016; Hazime et al., 2012). To the best of our knowledge there is no
309 guideline on an integrated postural and proprioceptive method in a reeducation program.
310 Results of the present study suggest a postural reeducation program in scoliotic girls
311 aimed at both improving proprioception while repositioning the mean CoP by postural
312 corrections.

313

314 **Conclusions**

315 Scoliotic girls appear to make a greater use of their hips or trunk rotations to maintain
316 their center of mass over the midline position evidence by a larger free moment and
317 medio-lateral axis coherence value at low frequencies and smaller coherence values at
318 high frequencies. This explains in part the large standard deviation value in scoliotic girls
319 to maintain a centered body CoP position implying postural control deficit. However,
320 both groups strongly privileged an ankle balance strategy to ensure their CoP antero-
321 posterior displacements over the other coherence relationships. In addition, the scoliotic
322 adolescents displayed a significantly higher mean free moment and CoP positions. This
323 could be related to a nearly 12 mm more rearward mean standing CoP position. Factor
324 analysis revealed that scoliotic girls systematically depend on the interaction between the
325 free moment for antero-posterior displacements of the CoP, emphasizing proprioception
326 control. Postural adaptations through the interactions between the CoP_{AP} and CoP_{ML}
327 positions regardless of the frequency bands were secondary to maintain standing balance.
328 The non-scoliotic girls controlled first their posture by the CoP positions along both axes
329 with the free moment and little by the CoP position. These results primarily suggest a

330 postural reeducation program aimed at improving proprioception while repositioning the
331 mean CoP in scoliotic girls.

332

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334

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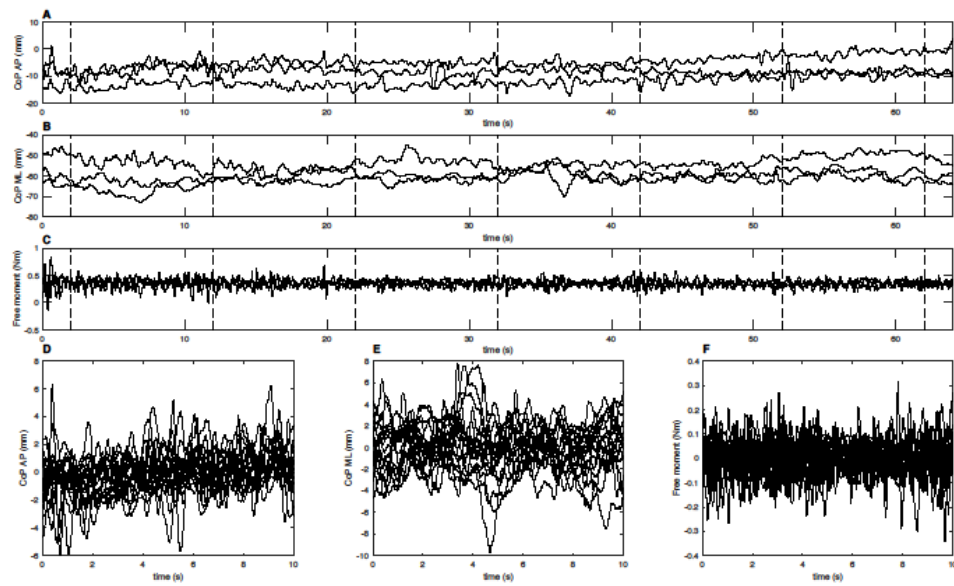


Fig. 1 The displacement of the center of pressure (CoP) in the antero-posterior (A) and mediolateral (B) axes and free moment, T_Z , (C) are shown for three 64 s trial of a non-scoliotic girl. The vertical dashed lines represent six 10s epochs. The signals of 18 10s epochs for the CoP_{AP} (D), CoP_{ML} (E) and T_Z (F) were then combined.

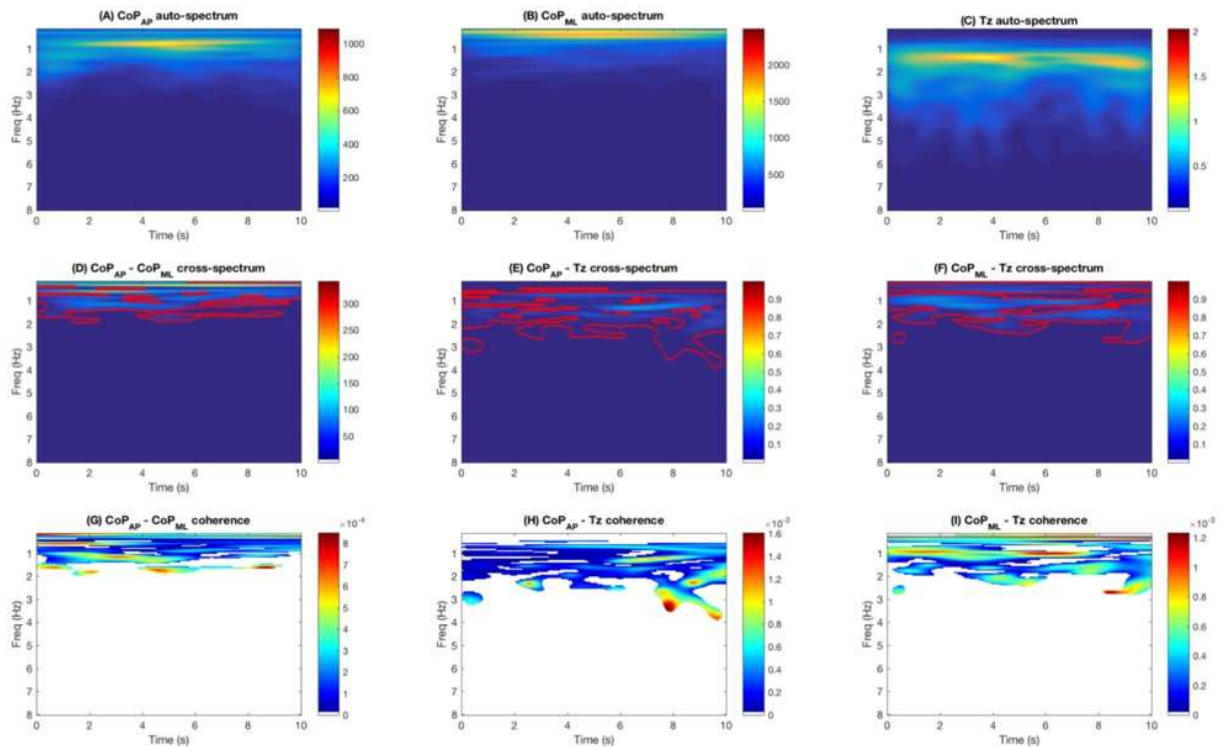
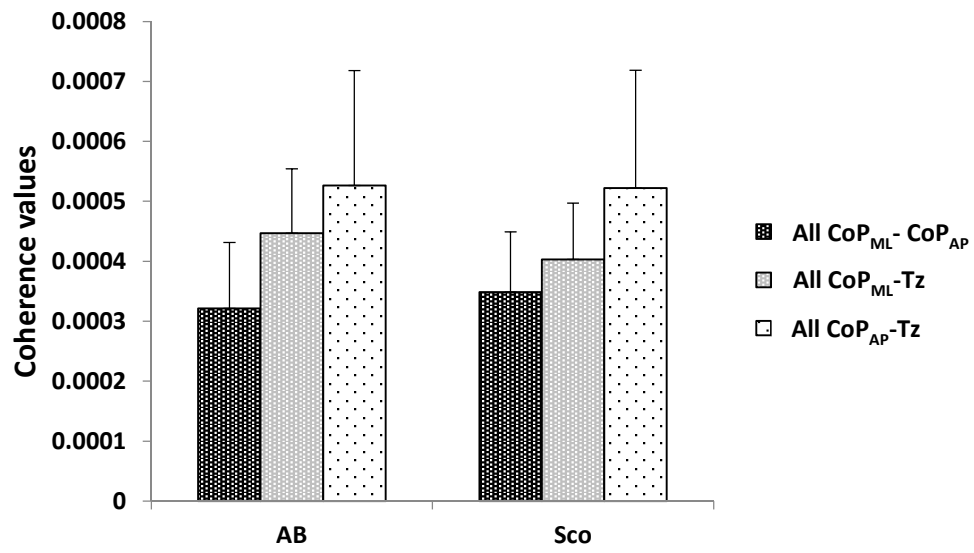
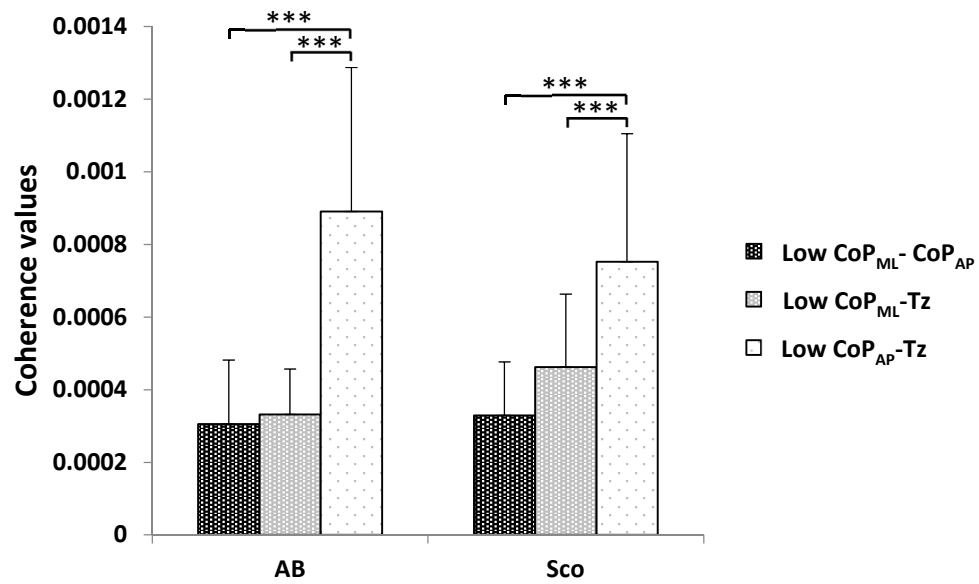


Fig. 2 Typical time-frequency representation of the CoP_{AP}, CoP_{ML} and Tz signals of one scoliotic participant. First row: Wavelet auto-spectra of the CoP_{AP} (A), CoP_{ML} (B) and Tz (C) signals. Second row: Wavelet cross-spectrum for CoP_{AP}-CoP_{ML} (D), CoP_{AP}-Tz (E) CoP_{ML}-Tz (F) signals; the red contours identify the areas in the time-frequency plane where the correlation between the two signals is significant. Third row: Wavelet magnitude-squared coherence for CoP_{AP}-CoP_{ML} (G), CoP_{AP}-Tz (H) CoP_{ML}-Tz (I) signals. All non-significant values are whitened. The magnitude of the coherence for each pair was quantified as the mean of significant magnitude-squared coherence over the entire time band in three frequency bands: overall (0.16-8.00 Hz), low (0.16-0.50 Hz) and high bands (0.50-8.00 Hz).

A**B**

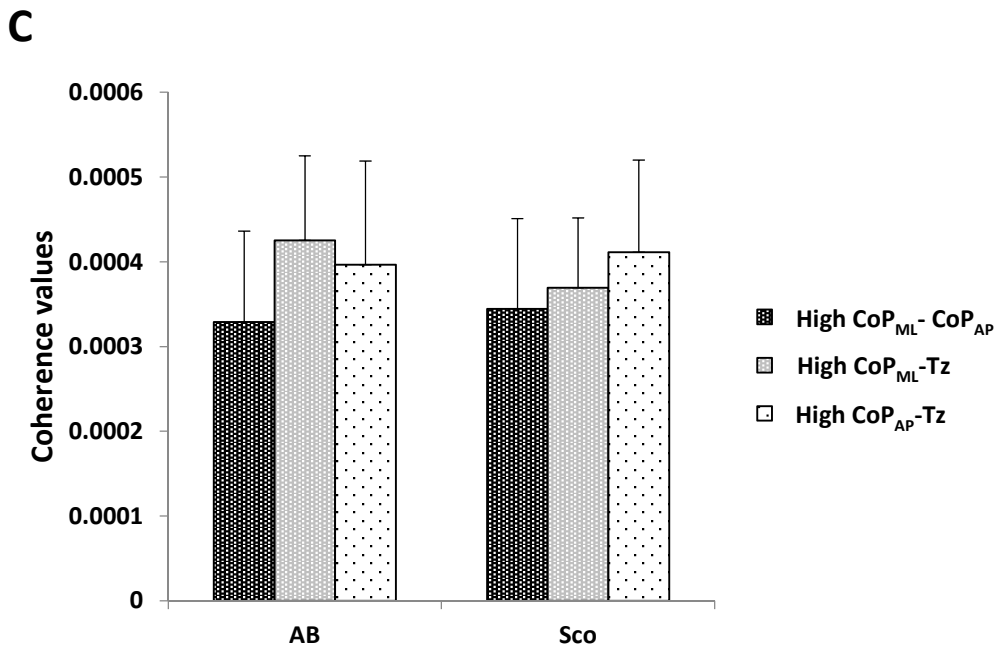


Fig. 3 Coherence values of the able-bodied (AB) and scoliotic (SCO) groups for the overall (A), low (B) and high (C) frequency bands. ***: $P < 0.001$.

Table 1 Mean and standard deviation of the CoP positions and coherence pairs for the overall, low and high frequency bands for the able-bodied (AB) and scoliotic (SCO) groups as well as their corresponding *P* values. Note: for display purpose only, all coherence values were multiplied by a 1000 factor. Mean (SD).

	Mean values (mm)		Overall			Low			High		
	CoP _{ML}	CoP _{AP}	CoP _{ML} -CoP _{AP}	CoP _{ML} -T _Z	CoP _{AP} -T _Z	CoP _{ML} -CoP _{AP}	CoP _{ML} -T _Z	CoP _{AP} -T _Z	CoP _{ML} -CoP _{AP}	CoP _{ML} -T _Z	CoP _{AP} -T _Z
AB	-3.1 (8.7)	-61.3 (13.2)	0.32 (0.11)	0.45 (0.11)	0.53 (0.19)	0.31 (0.18)	0.33 (0.12)	0.89 (0.40)	0.33 (0.11)	0.43 (0.10)	0.40 (0.12)
SCO	-2.9 (13.9)	-72.8 (14.7)	0.35 (0.10)	0.40 (0.09)	0.52 (0.20)	0.33 (0.15)	0.46 (0.20)	0.75 (0.35)	0.34 (0.11)	0.37 (0.08)	0.41 (0.11)
<i>P</i> value	0,937	0,005	0,365	0,127	0,941	0,608	0,012	0,197	0,616	0,033	0,665

Table 2 The significant factors and their respective loading values are given for the able-bodied (AB) and scoliotic groups. PC1, PC2, PC3 are the first three principal components of the factor analysis. Values equal or above 0.7 are in bold.

AB	PC1	PC2	PC3
High COP _{AP} -Tz	0,918	-0,074	0,022
All COP _{AP} -Tz	0,890	-0,347	0,122
High COP _{AP} -COP _{ML}	0,791	0,345	-0,027
All COP _{ML} - Tz	-0,057	0,953	0,012
High COP _{ML} - Tz	-0,071	0,916	0,040
Low COP _{ML} - Tz	0,299	0,195	0,854
Low COP _{AP} - COP _{ML}	0,425	0,453	-0,642

Scoliotic	PC1	PC2	PC3
All COP _{AP} -Tz	0,966	0,165	0,109
Low COP _{AP} -Tz	0,879	-0,096	0,049
High COP _{AP} -Tz	0,790	0,446	0,144
All COP _{AP} - COP _{ML}	0,050	0,983	0,065
High COP _{AP} - COP _{ML}	0,065	0,833	0,243
Low COP _{AP} - COP _{ML}	0,141	0,689	-0,273
All COP _{ML} - Tz	0,314	-0,009	0,910
High COP _{ML} - Tz	0,436	0,049	0,776
Low COP _{ML} - Tz	-0,228	0,036	0,732