Comparison of Pedobarographic Profile in Young Males with Left and Right Scoliotic Posture

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Keywords: Scoliosis, Posture, Gait, Plantar Pressure, Movement Compensation.

Abstract: *Background:* Scoliosis alters both posture and gait. Pedobarography is a biomechanical method for assessing gait that has been rarely used in scoliosis-specific gait research. *Objective:* To determine differences between left and right scoliotic posture in plantar pressure and force gait profile among young males. *Methods:* Twenty-one young, trained males assigned to one of two groups: left scoliotic posture (LSP; N=12) and right scoliotic posture (RSP; N=9) group. Subjects were assigned to a group based on forward-bending test and controlled for age, height, weight, body mass index (BMI), right and left leg length. All subjects were blinded for group they were assigned and study outcomes. Examiners were blinded for study outcomes. Subjects walked at self-selected speed along the 9,5-meter-long walkway for 2 minutes. Plantar pressures and forces were measured using pedobarographic device Zebris medical FDM 1.5. Measured outcomes during gait included: Maximum force right foot (N), Maximum force left foot (N), Maximum force at first contact right foot (N), Maximum force at first contact left foot (N), Maximum force at take-off right foot (N), Maximum force at take-off left foot (N), Maximum forefoot force right foot (N), Maximum forefoot force left foot (N), Maximum midfoot force right foot (N), Maximum midfoot force left foot (N), Maximum heel force right foot (N), Maximum heel force left foot (N), Maximum forefoot pressure right foot (N/cm^2), Maximum forefoot pressure left foot (N/cm^2), Maximum midfoot pressure right foot (N/cm^2), Maximum midfoot pressure left foot (N/cm^2), Maximum heel pressure right foot (N/cm^2), Maximum heel pressure left foot (N/cm^2). *Results:* There were no significant differences in any observed foot pressure or force gait parameter between left and right scoliotic posture group ($p<0,05$). *Conclusion:* Plantar pressure and force gait parameters seems to have no diagnostic value in determining scoliosis-specific gait. Focus should be shifted to other pedobarographic gait parameters (e.g. center of pressure, time-force parameters, etc.). Future research should investigate relationships between biomechanical movement compensation and neuromuscular, musculo-skeletal and genetic factors that may initiate scoliosis.

1 INTRODUCTION

Scoliosis is a deformity of the spine which results in lateroflexion of spine and vertebral rotations. Because scoliosis alters posture, it can also alter gait (Schultz, 1984). Gait altered by scoliosis can be objectively described through biomechanical analysis (Simon et al., 2015). However, scoliosis-specific gait is still controversial topic, because of inconclusive research (Karimi et al., 2015).

Some studies show significantly lower trunk range of motion (ROM) between scoliotic and healthy subjects (Engsberg et al., 2001; Mahaudens et al., 2009; Mahaudens and Mousny, 2010). Other show no differences in trunk ROM between scoliotic and healthy subjects (Yang et al., 2013; Park et al., 2016a; Schmid et al., 2016). Chen et al. (1998) concluded that scoliotic individuals manifest smaller spinal ROM in frontal plane, but the same in shoulder sagittal, frontal plane and spine sagittal plane as their healthy counterparts. Two studies (Kramers-de Quervain et al., 2004; Yang et al., 2013) found asymmetries in trunk ROM in scoliotic patients. However, it seems that there is no evidence for relationship between scoliotic severity and trunk ROM asymmetries (Mahaudens et al., 2009; Mahaudens and Mousny, 2010).

Pelvic ROM differences between scoliotic and non-scoliotic groups also show conflicting results (Chen et al., 1998; Chow et al., 2006; Mahaudens et al., 2009; Mahaudens and Mousny, 2010; Park et al., 2016a). Correlations between pelvic motions and scoliotic severity are non-existing or week (Kramers-de Quervain et al., 2004; Mahaudens et al., 2009;

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Mahaudens and Mousny, 2010; Syczewska et al., 2010; Syczewska et al., 2012; Yang et al., 2013).

In spatio-temporal characteristics of gait (e.g. walking speed, cadence, step length, stride length, etc.) scoliotic individuals tend to be slower and have shorter steps compared to non-scoliotic individuals (Chern et al., 1998; Engsberg et al., 2001; Mahaudens et al., 2009; Park et al., 2016a). But more studies show no differences (Chen, et al., 1998; Kramers-de Quervain et al., 2004; Chow et al., 2006; Mahaudens et al., 2009; Yang et al., 2013; Schmid et al., 2016). This might be because of weak to moderate test–retest reliability of spatio-temporal gait parameters (Fortin et al., 2008). Also, spine operation may be a factor that can explain heterogeneity in results (Lenke et al., 2001). Step length seem to be positively correlated with vertebrae rotation and negatively correlated with Cobb angle (Syczewska et al., 2010; Syczewska et al., 2012).

EMG activity revealed longer contraction of trunk and pelvis muscles during stride in scoliotic patients compared to non-scoliotic individuals (Mahaudens et al., 2009; Mahaudens and Mousny, 2010). Interestingly, there were no differences in EMG activity in left-right asymmetries among scoliotic patients. Furthermore, no differences were observed in EMG activity among patients with mild, moderate and severe scoliosis (Mahaudens et al., 2009; Mahaudens and Mousny, 2010).

Research based on ground reaction forces (GRF) appear to have more consistent findings. Most of the studies suggest that there is association between scoliosis and GRF parameters, especially in right and left foot asymmetry (Chockalingam et al., 2004; Chockalingam et al., 2008; Bruyneel et al., 2009; Chern et al., 2014; Yang et al., 2014; Park et al., 2016b). Another interesting finding is that GRF parameters tend to have larger variability in scoliotic patients compared to non-scoliotic individuals (Giakas et al., 1996; Chockalingam et al., 2008).

GRF parameters have higher test-retest reliability then kinematic parameters among scoliotic patients (Fortin et al., 2008). However, pedobarographic measurement devices (PMD) haven`t been used to describe scoliosis-specific gait. Kinetic platforms have been used in majority of scoliotic research, although PMD have shown their clinical usefulness (Lord et al., 1986; Putti et al., 2008; Giacomozzi, C., 2010).

The purpose of this study is to determine whether there are differences between left and right scoliotic posture in pedobarographic gait profile among young males.

2 METHODS

2.1 Subjects

Sample consists of 21 young, trained males assigned to one of two groups: left scoliotic posture and right scoliotic posture group. Subjects were assigned to group based on forward-bending test (Horne et al., 2014) which is explained in section 2.4 Scoliotic posture assessment. All subjects were blinded for group they were assigned and study outcomes.

Inclusion criteria:

1) people with scoliosis or scoliotic posture,
2) males,
3) age range between 18 and 25 years,
4) regular participation in any sport or recreational workout.

Exclusion criteria:

1) lower extremity injuries (e.g. ankle distortion, knee trauma, etc.),
2) musculo-skeletal diseases (e.g. arthritis, ankylosing spondylitis, etc.),
3) postoperative procedures within 6 months (e.g. anterior cruciate ligament surgery, hip surgery, etc.),
4) neurological diseases (e.g. neuropathy, cerebral palsy, etc.),
5) vascular diseases (e.g. intermittent claudication…),
6) metabolic diseases (e.g. diabetic foot, obesity…).

2.2 Pedobarographic Measurement

Plantar forces and pressures were measured by pedobarographic device Zebris medical platform FDM 1.5 (ZMP).

ZMP dimensions are 158.0 x 60.5 x 2.5 cm (Length x Wide x Height) with sensor area of 149.0 x 54.2 cm (Length x Wide). There are 11264 capacitive sensors in sensor area that register changes in force applied on ZMP per each cm^2. Sampling rate for this gait protocol was set on 300 Hz Pressure measuring range was between 1 and 60 N/cm^2.

WinFDM software for Windows operating system was used to gather and analyze raw data obtained from ZMP. Although, WinFDM generates reports with both graphical and quantitative data (figures 1, 2), only quantitative data were used for analyses.

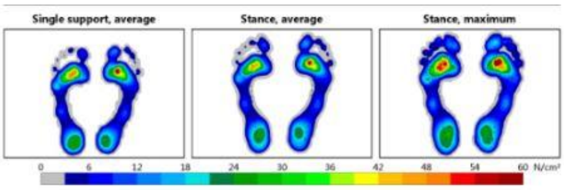

Figure 1: Part of generated report from WinFDM software for pedobarographic analysis.

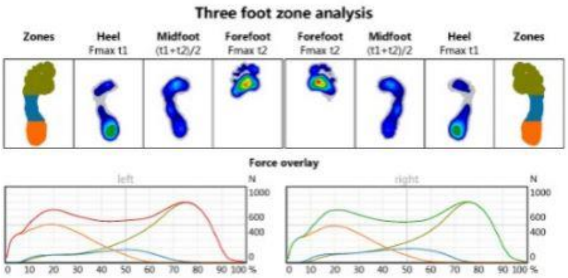

Figure 2: Part of generated report from WinFDM software for pedobarographic analysis.

Pedobarographic force parameters were expressed in newtons (N). Pedobarographic pressure parameters were expressed in newtons per centimeter squared (N/cm^2)

ZMP is shown to be reliable and accurate diagnostic device (Gruić et al., 2015). Diagnostician who performed pedobarographic measurement was blinded for study outcomes.

2.3 Anthropometric Measurement

Five anthropometric characteristics were determined: height, weight, body mass index (BMI), right and left leg length. Differences in these anthropometric characteristics can cause differences in pedobarographic profile (Dillon et al., 2008; Song et al., 1997). Therefore, both groups should be similar in these characteristics. Examiners who performed anthropometric measurement were blinded for study outcomes.

Height was measured with anthropometer. Subject was standing straight barefoot with his heels connected. Head was looking straight forward. In this position, anthropometer was parallel with the subject. The horizontal prong of anthropometer was placed on vertex (highest point on head). Examiner then read the value on anthropometer. Height was expressed in centimeters (cm). Weight was measured with digital scale. Subject was standing still and barefoot on digital scale until examiner read value on scale. Weight was expressed in kilograms (kg).

Leg length was measured with anthropometer. Subject was standing straight barefoot with his feet hip-width apart. In this position, anthropometer was parallel with the subject's leg. The horizontal prong of anthropometer was placed on subject`s spina iliaca anterior superior (SIAS). Leg length was expressed in centimeters (cm).

BMI was calculated using data from measured height and weight with formula (1):

$$BMI = \frac{\text{Weight (kg)}}{Height^2\ (m^2)} \quad (1)$$

BMI was expressed in kilograms per meter squared (kg/m^2).

2.4 Scoliotic Posture Assessment

Adam's forward bend test was used to assesses weather subject has left or right scoliosis or scoliotic posture (Horne et al., 2014). Subject bends over with his head and arms relaxed. The examiner looks subject from behind horizontally along the contour of the back.

If the gibbous is on the right side, then the subject was assigned to the right scoliosis/scoliotic posture. If the gibbous is on the left side, then the subject was assigned to the left scoliosis/scoliotic posture.

2.5 Gait Protocol

Protocol was performed in Biomechanics Laboratory of Faculty of Kinesiology, University of Zagreb every working day from 07:30 to 16:00 h.

prior to each protocol, subjects were instructed to develop their usual walking speed and to not look or aim ZMP.

Immediately before protocol started, subject was standing directly in line with ZMP and 4 meters away. When the subject was ready he started walking to the end of walking track, which is 9,5 meters away. At the end of walking track, subject turned 180º and walked back to starting point. Subject walked for 2 minutes with his usual walking speed.

Unsuccessful protocol was considered if the subject during 2-minute protocol:

1) altered his walk by aiming the ZMP,
2) had less than 3 full feet steps on ZMP,
3) was distracted.

In a case of unsuccessful protocol, measurement was terminated and repeated.

2.6 Statistical Analysis

Microsoft Excel 2016 and Statistica 12 for Windows operating system was used for statistical analysis.

Arithmetic mean (AM) and standard deviation (SD) was used to describe anthropometric characteristics and pedobarographic gait profile of subjects.

Mann-Whitney U Test was used to determine statistical significance of differences between groups in anthropometric characteristics and foot pressure and force gait profile of subjects.

3 RESULTS

Subjects were homogenous in all observed anthropometric characteristics. No significant differences in age, BMI, weight, height, right and left leg length between two groups (table 1).

Table 1: Anthropometric characteristics of subjects.

Variables	Left scoliotic posture group N=12	Right scoliotic posture group N=9	p value
Age (years)	22,00 ± 1,41	21,11 ± 0,93	0.12
BMI (kg/m2)	25,22 ± 2,57	24,10 ± 1,46	0.11
Weight (kg)	83,01 ± 11,63	80,46 ± 8,75	0.78
Height (cm)	181,22 ±7,86	182,48 ± 6,41	0.55
Right leg length (cm)	103,51 ± 5,02	102,71 ± 4,63	0.97
Left leg length (cm)	103,41 ± 5,34	102,44 ± 4,54	1.00

There were no significant differences in any observed foot pressure or force gait parameter between left and right scoliotic posture group in this sample (table 2).

4 DISCUSSION

There are no differences in any observed foot pressure or force parameter between left and right scoliotic posture group in this study, suggesting that scoliotic posture is not associated with those parameters. These findings are consistent with studies from this field that assessed asymmetries in force components of GRF (Giakas et al., 1996; Chockalingam et al., 2004; Yang et al., 2013; Park et al., 2016b).

Possible explanation for absence of any asymmetries in foot pressure and force gait parameters for people with scoliotic posture can be movement compensation. It is speculated that from primary spine curvature downward a series of movement compensations occur during gait. These movement compensations can balance asymmetries caused by scoliosis. This might be the reason why differences between scoliotic and non-scoliotic individuals are seen in EMG (Mahaudens et al., 2009; Mahaudens and Mousny, 2010), kinematic (Chen et al., 1998; Engsberg et al., 2001; Kramers-de Quervain et al., 2004; Mahaudens et al., 2009; Mahaudens and Mousny, 2010; Syczewska et al., 2010; Syczewska et al., 2012; Yang et al., 2013; Park et al., 2016a), spatio-temporal (Chen et al., 1998; Lenke et al., 2001; Engsberg et al., 2001; Mahaudens et al., 2009; Syczewska et al., 2010; Park et al., 2016a) and some components of kinetic parameters (Giakas et al., 1996; Chockalingam et al., 2004; Chockalingam et al., 2008; Bruyneel et al., 2009; Chern et al., 2014; Yang et al., 2014; Park et al., 2016b), but not in force components of ground reaction forces (Giakas et al., 1996; Chockalingam et al., 2004; Yang et al., 2013; Park et al., 2016b).

4.1 Study Limitations

There are several limitations of this study that should be addressed in future studies. Most of subjects in this study did have scoliotic posture which is mild form of scoliosis. Adam's forward bend test is known as inaccurate screening tool (Deurloo and Verkerk, 2015; Fong et al., 2010). This means that there is possibility that some subjects who are healthy are classified into left or right scoliotic posture group. This problem can be avoided with classification of scoliotic posture based on Cobb angle method. Second limitation is that only force and pressure parameters were used to determine pedobarographic gait profile. Inclusion of other pedobarographic parameters (e.g. step length, step width, walking speed, center of pressure, etc.) is advised (Giacomozzi, 2011). Third limitation is that subjects weren`t measured in the same time of the day. Some were measured in the morning, while others afternoon, depending on their availability. Another limitation of this study is small sample size. Also, this study didn`t include females. Females tend to have different gait profile from man (Ko et al., 2011).

Table 2: Pedobarographic gait profile for left scoliotic and right scoliotic posture among young males.

Variables	Left scoliotic posture group N=12	Right scoliotic posture group N=9	p value
Maximum force right foot (N)	869,30 ± 152,67	846,13 ± 133,75	0.27
Maximum force left foot (N)	840,90 ± 163,90	829,33 ± 209,92	0.92
Maximum force at first contact right foot (N)	819,43 ± 160,76	790,18 ± 210,44	0.30
Maximum force at first contact left foot (N)	848,53 ± 148,56	804,14 ± 125,19	0.64
Maximum force at take-off right foot (N)	809,45 ± 166,65	840,91 ± 135,36	0.97
Maximum force at take-off left foot (N)	795,53 ± 173,71	810,44 ± 210,21	0.70
Maximum forefoot force right foot (N)	831,42 ± 99,31	828,82 ± 125,68	0.59
Maximum forefoot force left foot (N)	818,28 ± 111,32	826,00 ± 121,91	0.97
Maximum midfoot force right foot (N)	170,14 ± 76,01	144,02 ± 61,07	0.52
Maximum midfoot force left foot (N)	154,75 ± 74,44	123,98 ± 61,68	0.30
Maximum heel force right foot (N)	588,41 ± 97,53	564,38 ± 128,32	0.46
Maximum heel force left foot (N)	603,24 ± 86,26	580,89 ± 127,08	0.59
Maximum forefoot pressure right foot (N/cm^2)	50,77 ± 10,79	44,46 ± 9,95	0.24
Maximum forefoot pressure left foot (N/cm^2)	46,94 ± 9,15	45,28 ± 9,73	0.64
Maximum midfoot pressure right foot (N/cm^2)	12,75 ± 4,00	12,66 ± 5,69	0.59
Maximum midfoot pressure left foot (N/cm^2)	13,28 ± 4,41	10,91 ± 3,96	0.27
Maximum heel pressure right foot (N/cm^2)	37,99 ± 11,02	39,41 ± 10,37	0.70
Maximum heel pressure left foot (N/cm^2)	39,76 ± 10,67	40,36 ± 10,27	0.67

4.2 Scientific Importance

Biomechanical movement compensations might be reactions to neuromuscular (Veldhuizen et al., 2000; Burwell, 2003; Cheung eta al., 2008), musculo-skeletal (Burwell, 2003; Cheung eta al., 2008) and/or genetic (Cheung eta al., 2008) factors that may cause scoliosis. Therefore, future research should investigate relationships between biomechanical movement compensation and neuromuscular, musculo-skeletal and genetic factors.

4.3 Practical Importance

As shown in this paper, not all biomechanical gait parameters can determine asymmetries caused by scoliosis. Also, some biomechanical gait parameters are better at detecting scoliosis-specific gait. It appears that pedobarographic force and pressure parameters can`t be used in determining scoliosis-specific gait abnormalities. Therefore, attention should be focused on other pedobarographic gait parameters (e.g. center of pressure, time-force parameters, etc.) as diagnostic tool for scoliosis-specific gait. Knowing which parameters can reveal scoliosis gait abnormalities does not have just diagnostic value, but it is also important for more effective scoliosis treatment prescription.

5 CONCLUSION

There are no differences in any observed foot pressure or force gait parameter between left and right scoliotic posture group. Plantar pressure and force gait parameters seems to have no diagnostic value in determining scoliosis-specific gait. Focus should be shifted on other pedobarographic gait parameters (e.g. center of pressure, time-force parameters, etc.) to determine scoliotic gait abnormalities. Future research should investigate relationships between biomechanical movement compensation and neuromuscular, musculo-skeletal and genetic factors that may initiate scoliosis.

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