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# Effect of short-term spinal orthosis and insoles application on cobb angle, plantar pressure and balance in individuals with adolescent idiopathic scoliosis

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ABSTRACT

*Background:* Spinal orthosis applications are preferred for conservative treatment of adolescent idiopathic scoliosis, and holistic biomechanical approaches are recommended.
*Methods:* This was single-blind, prospective, randomized, controlled study. It included 42 patients (29 females/13 males) aged 10–18 years with adolescent idiopathic scoliosis, Cobb angle of 20°–45°, who were deemed suitable for spinal orthosis use. Patients were randomly divided into two groups: control, spinal orthosis group ($n = 21$), and insoles and spinal orthosis group (n = 21). All participants used spinal orthoses for 3 months. This study evaluated the functional capacities, quality of life, balance, and plantar pressures of the participants. The evaluations were repeated after 1 week, and 3 months following spinal orthosis application.
*Findings:* Statistically significant difference and positive effect were observed in Cobb angle ($p = 0.008$; $p = 0.878$, respectively), right total ($p = 0.037$; $p = 0.193$, respectively), left total (p = 0.037; p = 0.193, respectively), left rearfoot ($p = 0.002$; $p = 0.708$, respectively), and right forefoot plantar pressure ($p = 0.001$; $p = 0.739$, respectively) in participants in insoles and spinal orthosis group compared with those in the control group. Statistically significant differences and positive effects were observed in swing length ($p = 0.001$; $p = 0.053$, respectively) and functional capacity ($p = 0.005$; $p = 0.220$, respectively), which are parameters related to postural balance. No change was found in quality of life of either group ($p > 0.05$).
*Interpretation:* Insoles may have positive impact on functional capacity, balance, and plantar pressure during long-term follow-up in individuals with scoliosis. Therefore, the evaluation of foot plantar pressure in individuals with scoliosis is recommended, and personalized insoles may be a beneficial option.

## 1. Introduction

Scoliosis is a three-dimensional deformity caused by rotation and lateral deviation of the vertebrae by >10° (Negrini et al., 2018). Adolescent idiopathic scoliosis (AIS) is the most prevalent type of scoliosis diagnosed in individuals aged ≥10 years (Cheng et al., 2015; Hresko, 2013).

Scoliosis can lead to dyspnea, fatigue, and have detrimental effects on various aspects of life, including functional capacity (FC), quality of life (QoL), psychosocial well-being, and cosmetic appearance (Amaricai et al., 2020; Vasiliadis and Grivas, 2008). Additionally, movement patterns may be altered during each step owing to changes in spinal alignment and body posture (Daryabor et al., 2017).

Scoliosis can also impact foot biomechanics, as gait relies on foot biomechanics, posture, and the harmonious interaction of the lower extremities, pelvis, and spine (Hmida et al., 2023). Proper spine functionality necessitates lower extremity stability, emphasizing the role of spine in walking (McGregor and Hukins, 2009). Scoliosis, as a spinal deformity, significantly affects not only the spine and lower extremities but also the entire musculoskeletal system (Haddas et al., 2018). Furthermore, all musculoskeletal issues are also influenced by plantar pressure (PP) changes (Razak et al., 2012). Abnormal spine alignment affects foot PP, which are associated with postural disorders. Individuals with scoliosis have been examined for distribution of PP (Horng et al., 2021). In most individuals with scoliosis, PP analysis parameters and the loads on the right and left feet differed (Zhu et al., 2021). Park et al.

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found that the difference in PP between the right and left foot was associated with scoliosis (Park et al., 2009). Postural balance and Cobb angle (CA) are also related to PP in individuals with scoliosis (Yi et al., 2021).

Conservative treatment is recommended for approximately 10% of the patients diagnosed with scoliosis, whereas surgery is recommended for only 0.3% of cases. Conservative methods typically involve exercise and the use of spinal orthosis. Generally, orthoses are preferred for individuals with a CA of 20°–45° (Hawary et al., 2019; Negrini et al., 2018). Spinal orthosis, when applied in AIS can help prevent the progression of deformity by counteracting external forces that influence the spinal curvature (Hollman et al., 2011; Seidler et al., 2010). The primary goal of spinal orthosis is to correct spinal curvature (Hmida et al., 2023; Xu et al., 2019).

Numerous studies have reported that foot orthoses can improve toe, ankle, and knee biomechanics (Lewinson and Stefanyshyn, 2016; Steinberg et al., 2016; Xiang et al., 2022). Furthermore, foot orthoses insoles can enhance biomechanics, compensation, posture, PP distributions, and gait (Xu et al., 2019). Correctioning of asymmetric PP in individuals with scoliosis can inducestransmit corrective forces transmitted to the lower extremities, pelvis, and spine, andpotentially may have an effect on reducing reducing the CA. It has been reported that iInsoles applied to individuals with AIS have positive effects ondemonstrated improvements in postural balance, and CA, as well as and positive effects on PP (Rothschild et al., 2020).

Insoles improve plantar pressure load distribution in individuals with pes planus after a 3-month follow-up (Zhai et al., 2019). Specifically, individually designed insoles can enhance gait parameters and foot pressure distribution (Xu et al., 2019).

Although many studies have examined how changes in spine posture affect the lower extremities (Tateuchi, 2019). few studies have investigated the reciprocal effect of the lower extremities and insoles on the spine.

This study aims to investigate the impact of short-term custom insoles on CA, PP, postural balance, FC, and QoL in individuals with AIS who are using spinal orthoses.

## 2. Methods

This is a single-blind, prospective, randomized study with a control group. The Istanbul Medipol University Ethics Committee approved the study (decision number 555, E-10840098-772.02-2505, dated 01.06.2021). It was registered in the clinical trial registry (www.clinicaltrials.gov, clinical ID No: NCT05479695).

### 2.1. Participants

Individuals diagnosed with AIS between June 2021 and April 2022, who were prescribed orthosis use and who applied to a private spinal orthosis application center were included in this study. The "Informed Participant Consent Form" and "Family Information Form" were obtained verbally and in writing from the participants and their parents.

Individuals aged 10–18 years with a CA of 20°-45 (Hawary et al., 2019; Negrini et al., 2018) with a diagnosis of AIS who were recommended to wear an orthosis for the first time and required to wear an orthosis for at least 20 h a day (Negrini et al., 2018) were included in this study. Individuals with neurological problems, mental retardation, a history of spine surgery, congenital lower extremity deformity, and insoles were excluded. We evaluated 64 individuals who visited the orthotic center for spinal orthotic application. We included 54 participants who met the inclusion criteria.

Pre-prepared sealed envelopes numbered 1–54 were used to randomize the study participants. Participants were asked to choose one of the closed envelopes, and randomization was achieved by including those who chose an odd number in the control, spinal orthosis group (SOG; $n = 27$) and those who chose an even number in the insoles and spinal orthosis group (ISOG; n = 27). Six participants from each group declined to continue the study, leaving 42 participants (29 females and 13 males). Fig. 1 shows the participant selection flowchart.

### 2.2. Procedure

The orthoses used by the participants included in the study were prescribed by a doctor and were applied by the same orthotist. The CA, PP, postural balance, FC, and QoL of participants were evaluated after 1 week of using spinal orthosis and during 3-month follow-up. CA measurements were recorded at the beginning of the study and after the follow-up.

PP, postural balance, and FC evaluation of all participants were performed with spinal orthosis. Additionally, PP analysis evaluated the barefoot of all participants.

In our study, the Sensor Medica Maxi (freeMed Maxi; Sensor Medica; Guidonia Montecelio, Roma, Italia) pedobarographic assessment device, which can measure a maximum pressure of 150 N/cm$^2$, had 3000 sensors, 2.5 dpi XY, 8-bit Z resolution, sensor life of 1,000,000 cycles, dimension of 60 × 50 cm, and aluminum sheet, and FreeStep software was used to evaluate foot PP analysis and postural balance (Pruijs et al., 1994). The static pressure analysis required barefoot platform walking. The instructions required the participant to stand bipedally on the platform, looking straight ahead and standing still. When the participant was in the specified position with their eyes open, the "start" button was pressed in the software. The analysis took 5 s. Postural balance was assessed using the sway test. The stages were explained to the participants before the test was conducted. The sway test was performed twice in a bipedal standing position with eyes open and closed. Each analysis took approximately 52.2 s. The participants were pedobarographically evaluated using a spinal orthosis.

The 6-min walk test (6MWT), developed by the American Thoracic Society and officially adopted in 2002 with comprehensive guidelines, was used to assess FC (Correale et al., 2020). Individuals were instructed to walk around a 30-m track on a flat, hard surface. During the test, individuals were instructed to stop or slow down if breathing, fatigue, or movement problems occurred. The distance covered in meters over 6 min (test, 2002) was recorded as the test measurement. The 6 MWT assessment was performed using a spinal orthosis.

The Scoliosis Research Society-22 questionnaire was used to assess the QoL. It is a questionnaire with proven validity and reliability in Turkish and other languages (test, 2002; Verma et al., 2010). A higher total score indicates increased QoL, whereas a lower score indicates decreased QoL (Verma et al., 2010).

All participants and the ISOG group's insoles were individually designed using a computer-aided design and computer-aided manufacturing system and manufactured using the Vulcan Computer Numerical Control (CNC) method (Alanay et al., 2005). Insoles production began with Sensor Medica Maxi evaluation. The data recorded in the FreeStep software program were used to design insoles specific to the foot structure of each individual using the Easycad program. The design of the insoles was aimed at equalizing the distribution of PP load between the feet of the individuals. Ethylene Vinyl Acetate (EVA) was used for the production of insoles. The EVA material was placed in the machine as a block, and personalized insoles were produced using the CNC method. After the insoles were produced, they were tested in the standing position to check the fit of the insoles with the foot. After the fitting, the necessary corrections were made, and the insoles were placed in the shoes and delivered.

### 2.3. Statistical analysis

The results of a study conducted by Noh et al. (Noh et al., 2014) were considered in the G*Power analysis using the G*Power 3.1.9.7 program to ensure that the sensitivity of the results was reliable. According to the effect size of 0.25 (moderate) of the measurements taken at two different

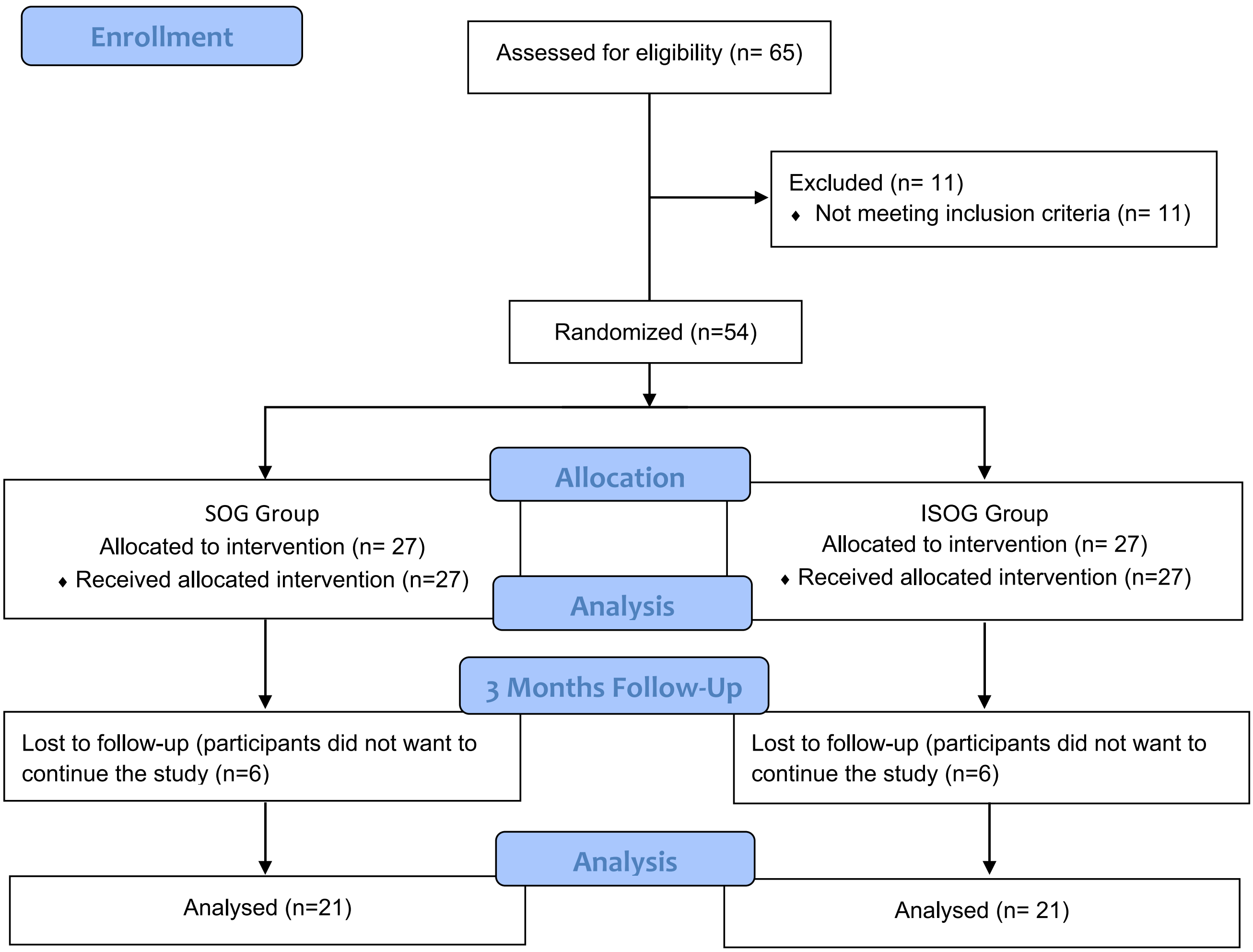


**Fig. 1.** Participants' selection flow chart.

times for the two independent groups, with 80% strength, 5% type I error, and at least 0.40 correlation between variables, it was appropriate to include a minimum of 40 people in the study, with at least 20 people in each group. We included 54 participants in the study, taking into account the possibility of 20% drop out rate.

The Shapiro–Wilk test was used to assess the continuous variable normality control. The studies used parametric tests because the variables were normally distributed. SOG and ISOG were compared using an independent means *t*-test. A paired t-test was used to compare the pre- and post-tests, and repeated measures analysis of variance (time × group interactions) was used to compare the pre-test and post-test changes between the groups. Chi-square and Fisher's exact-tests were used to analyze categorical data. Descriptive statistics for continuous variables were expressed as mean, standard deviation, and minimum and maximum values, and categorical data were expressed as frequencies and percentages. Data were evaluated using IBM SPSS 21 software.

## 3. Results

### 3.1. Baseline data / participants

We included 54 participants this study, and the study was completed

**Table 1**
Basic demographic and clinical information of the groups.

| Groups | N | Gender n (%) | BMI (SD) | Curve type n (%) | Major curve n (%) | Major curvature direction n (%) | Risser rade n (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 0 | 1 | 2 | 3 | 4 | 5 |
| SOG | 21 | W: 14 (66.7) M: 7 (33.3) | 19.08 (3.62) | One: 2 (9.5) Double: 19 (90.5) | L: 15 (71.4) T: 6 (28.6) | R: 6 (28.6) L: 15 (71.4) | 0 | 1 (4.76) | 5 (23.8) | 12 (57.14) | 2 (9.52) | 1 (4.76) |
| ISOG | 21 | W: 15 (71.4) M: 6 (28.6) | 20.33 (5.13) | One: 1 (4.8) Double: 20 (95.2) | L: 14 (66.7) T: 7 (33.3) | R: 10 (47.6) L: 11 (52.4) | 0 | 0 | 8 (38.09) | 11 (52.38) | 2 (9.52) | 0 |
| $p_{group}$ | | *0.739* | *0.363* | *1.0* | *0.739* | *0.204* | *0.528* | | | | | |

Abbreviations: *p*group: Independent Means *t*-test; *p*: chi-square test *Fisher Exact test; BMI: Body Mass Index; W: Woman; M: Male; L: Lumbal; T: Thoracal; L: Left; R: Right; SOG: Control group using spinal orthosis; ISOG: Group using insoles with spinal orthosis; Data expressed as mean (SD); $p < 0.05$ was considered to be significant with 42 participants (29 females and 13 males). Table 1 shows demographics and clinical information of the participants. No statistically significant differences were observed between the groups ($p > 0.05$).

### 3.2. Cobb angle

Table 2 shows the intra- and inter-group pre- and post-test comparisons of the CA measurement values of the participants. In the intra-group pre-test–post-test comparison, there was a statistically significant difference in the CA of the participants in ISOG ($t = 2.924$, $p = 0.008$), whereas there was no significant difference in that of the participants in SOG ($t = 0.156$, $p = 0.878$).

### 3.3. Static plantar pressure analysis

Table 3 shows the intra- and inter-group pre-test–post-test comparisons of the total, rearfoot foot, and forefoot loading measurement values of the participants' right- and left-foot static PP analyses. In the intra-group total foot loading pre-test–post-test comparison, a statistically significant difference was observed in participants in ISOG in the right and left feet ($t = -2.230$, $p = 0.037$; $t = 2.30$, $p = 0.037$, respectively), whereas no significant difference was observed in participants in SOG ($t = 1.348$, $p = 0.193$; $t = -1.348$, $p = 0.193$, respectively). In the in-group rearfoot loading pre-test–post-test comparison, no statistically significant difference was observed in the right foot of participants in ISOG ($t = 0.733$, $p = 0.472$), a significant difference in the left foot ($t = 3.668$, $p = 0.002$), and no significant difference in the right and left foot of participants in SOG ($t = 0.696$, $p = 0.494$; $t = 0.381$, $p = 0.708$, respectively). In the intra-group forefoot loading pre-test–post-test comparison, a statistically significant difference was found in the right foot of participants in ISOG ($t = -3.928$, $p = 0.001$), whereas no statistically significant difference was found in the left foot ($t = -1.997$, $p = 0.060$). Among participants in SOG, no significant difference was observed in the right foot ($t = -0.338$, $p = 0.739$), whereas a significant difference was observed in the left foot ($t = -2.646$, $p = 0.016$).

### 3.4. Assessment of postural balance

Table 4 shows intra- and inter-group pre-test–post-test comparisons of the participants' sway test (eyes open and closed) measurements. In the intra-group sway length pre-test–post-test comparison, a statistically significant difference was found in participants in ISOG in the eyes-open condition ($t = 4.421$, $p = 0.001$), whereas no statistically significant difference was found in the eyes-closed condition ($t = 1.928$, $p = 0.068$). In participants in SOG, there was no statistically significant difference between the eyes open and closed conditions ($t = 2.060$, $p = 0.053$ and $t = 0.921$, $p = 0.069$, respectively). In the pre-test–post-test comparison of the intra-group oscillatory ellipse area, Delta X, and Delta Y parameters, there was no statistically significant difference between participants in ISOG with eyes open ($t = -1.190$, $p = 0.248$; $t = 0.299$, $p = 0.768$; $t = -1.143$, $p = 0.266$, respectively) and eyes closed ($t = 0.141$, $p = 0.889$; $t = -0.710$, $p = 0.486$; $t = -0.520$, $p = 0.609$). Similarly, no statistically significant difference was found between eyes open ($t = -1.491$, $p = 0.152$; $t = -1.751$, $p = 0.095$; $t = -0.170$, $p = 0.867$, respectively) and eyes closed conditions ($t = 1.231$, $p = 0.232$; $t = 1.037$, $p = 0.312$; $t = 0.470$, $p = 0.643$, respectively) in participants in SOG.

Table 5 shows the pre-test and post-test comparisons of the FC and QoL measurement values of the participants within and between groups. In the intra-group pre-test–post-test comparison, FC showed a statistically significant difference in participants in ISOG ($t = -3.174$, $p = 0.005$), whereas no significant difference was observed in participants in SOG ($t = -1.266$, $p = 0.220$). In the in-group pre-test–post-test comparison, QoL was not significantly different between participants in ISOG and SOG ($t = 0.822$, $p = 0.421$; $t = 0.811$, $p = 0.427$, respectively).

**Table 2**
Descriptive statistics for cobb angle.

| | N | Pre-test. Mean (SD) | Post-test. Mean (SD) | Within-group difference Mean (SD) | 95% CI for diff. | $P_{pair}$ | Effect size ($\eta_p^2$) |
|---|---|---|---|---|---|---|---|
| Cobb angle (°) | | | | | | | |
| SOG | 21 | 28.56 (5.19) | 28.43 (6.92) | −0.13 (3.78) | −1.59-1.85 | *0.878* | 0.001 |
| ISOG | 21 | 30.58 (7.25) | 28.61 (6.77) | −1.97 (3.09) | 0.57–3.38 | ***0.008*** | 0.300 |
| $p_{group}$ | | *0.305* | *0.932* | *0.092* | | | |

Abbreviations: *p*group: Independent Means t-test; $p_{pair}$: Paired t-Test; $\eta_p^2$: Partial eta square; Effect size: small effect = 0.009, medium effect = 0.058, and large effect = 0.137; SOG: Control group using spinal orthosis; ISOG: Group using insoles with spinal orthosis; Data expressed as mean (SD); $p < 0.05$ was considered to be significant; Bold values indicate that it is statistically significant ($p < 0.05$).

## 4. Discussion

In this randomized controlled study, we assessed the impact of insoles on CA, PP, postural balance, FC, and QoL in individuals with AIS using spinal orthoses.

Studies have reported that girls and children with low BMI have a higher risk of scoliosis and progression (Fadzan and Bettany-Saltikov, 2017; Kim et al., 2020; Noh et al., 2014). The curvature pattern and the Risser stage also play a crucial role in the conservative treatment of scoliosis with spinal orthoses (Stokes et al., 2009). Consistent with literature, most of our study participants were female, and the mean BMI of the participants fell within the normal range. Some participants exhibited a "one curve" in the thoracic region, classified as Type-4 according to the King classification, whereas others presented with a "double curve," primarily classified as Type-2.

Previous research has indicated that foot orthoses applied to individuals with scoliosis positively impact CA (Park et al., 2016; Rothschild et al., 2020). Our study results align with these findings, demonstrating a statistically significant reduction in CA in individuals using spinal orthosis and insoles (Park et al., 2016; Rothschild et al., 2020), highlighting the importance of foot analyses in scoliosis management. Alongside conservative treatment, individually designed insoles may be a recommendation.

Although spinal orthoses treatment is generally not highly recommended for individuals with Risser stage ≥3 (Kawasaki et al., 2020; Rothschild et al., 2020), most participants in our study were at Risser stage 3. Our findings suggest that spinal orthosis may be a viable choice in conservative treatment for individuals with Risser stage ≥3. Further research on the long-term effects of spinal orthoses in individuals with Risser stage ≥3 is warranted.

Biomechanical factors involving the foot and pelvis have known effects on the spine (Buldt et al., 2013; Lucas and Cornwall, 2017). The asymmetry caused by vertebral column and trunk scoliosis negatively impacts the distribution of PP loads on the feet (Buldt et al., 2013; Lucas and Cornwall, 2017).

Static PP evaluations of female patients with AIS exhibiting a right thoracic curve have shown variations in loading percentages between the right and left feet (Buldt et al., 2018). After a 3-month follow-up, our study revealed that the difference in total loading percentage between the two feet was less pronounced compared with that reported in a previous study (Zhu et al., 2021). This discrepancy may be attributed to the analysis being performed using spinal orthoses, which corrected the spinal alignment toward the frontal midline. The improved front load balance may account for the statistically higher foot load balance observed in the insole group. Studies (da Silveira et al., 2022; Szulc et al., 2008) on spinal orthoses and PP have also reported decreased rearfoot loading, consistent with our findings. The reduction was statistically significant in the group using insoles, suggesting that insoles

**Table 3**
Descriptive statistics for static analysis plantar pressure loading percentages pretest and posttest measurements.

| Foot Loading Zones | Direction | Groups | *N* | Pre-test. Mean (SD) | Post-test. Mean (SD) | Within-group difference Mean (SD) | 95% CI for diff. | $P_{pair}$ | Effect size ($\eta_p^2$) |
|---|---|---|---|---|---|---|---|---|---|
| Total loading (%) | Right | SOG | 21 | 50.14 (4.09) | 48.1 (6.56) | −2.05 (6.96) | −1.12-5.22 | *0.193* | 0.083 |
| | | ISOG | 21 | 45.86 (6.22) | 49.29 (4.29) | +3.43 (7.05) | −6.64-0.22 | ***0.037*** | 0.199 |
| | | $p_{group}$ | | ***0.012*** | *0.491* | ***0.015*** | | | |
| | Left | SOG | 21 | 49.86 (4.09) | 51.9 (6.56) | +2.05 (6.96) | −5.22-1.12 | 0.193 | 0.083 |
| | | ISOG | 21 | 54.14 (6.22) | 50.71 (4.29) | −3.43 (7.05) | 0.22–6.64 | **0.037** | 0.199 |
| | | $p_{group}$ | | ***0.012*** | *0.491* | ***0.015*** | | | |
| Rearfoot loading (%) | Right | SOG | 21 | 30.95 (4.17) | 29.95 (7.14) | −1 (6.58) | −2-4 | *0.494* | 0.024 |
| | | ISOG | 21 | 29.24 (4.77) | 28 (5.87) | −1.24 (7.74) | −2.28-4.76 | *0.472* | 0.026 |
| | | $p_{group}$ | | *0.222* | *0.339* | *0.915* | | | |
| | Left | SOG | 21 | 30.1 (4.07) | 29.52 (6.85) | −0.57 (6.88) | −2,56-3,7 | *0.708* | 0.007 |
| | | ISOG | 21 | 34.05 (6.19) | 29.19 (5.76) | −4.86 (6.07) | 2.09–7.62 | ***0.002*** | 0.402 |
| | | $p_{group}$ | | ***0.019*** | *0.865* | *0.038* | | | |
| Forefoot loading (%) | Right | SOG | 21 | 19.19 (4.19) | 19.62 (6.58) | +0.43 (5.82) | −3,08-2,22 | 0.739 | 0.006 |
| | | ISOG | 21 | 16.62 (4.38) | 21.29 (5.47) | +4.67 (5.44) | −7.14-2.19 | **0.001** | 0.436 |
| | | $p_{group}$ | | *0.059* | *0,378* | ***0.019*** | | | |
| | Left | SOG | 21 | 19.76 (4.09) | 23.76 (6.97) | +4 (6.93) | −7.15-0.85 | **0.016** | 0.259 |
| | | ISOG | 21 | 20.1 (3.69) | 22.52 (5.15) | +2.43 (5.57) | −4.97-0.11 | 0.060 | 0.166 |
| | | $p_{group}$ | | *0.783* | *0.517* | *0.423* | | | |

Abbreviations: *p*group: Independent Means t-test; $p_{pair}$: Paired t-Test; $\eta_p^2$: Partial eta square; Effect size: small effect = 0.009, medium effect = 0.058, and large effect = 0.137; SOG: Control group using spinal orthosis; ISOG: Group using insoles with spinal orthosis; Data expressed as mean (SD); $p < 0.05$ was considered to be significant; Bold values indicate that it is statistically significant ($p < 0.05$).

**Table 4**
Descriptive statistics for postural balance team pretest and posttest measurements.

| Sway test parameters | Eyes state | Groups | *N* | Pre-test. Mean (SD) | Post-test. Mean (SD) | Within-group difference Mean (SD) | 95% CI for diff. | $P_{pair}$ | Effect size ($\eta_p^2$) |
|---|---|---|---|---|---|---|---|---|---|
| Sway Length (mm) | OE | SOG | 21 | 758.7 (176.71) | 654.57 (210.52) | −104.13 (231.63) | −1.3-209.57 | *0.053* | 0.175 |
| | | ISOG | 21 | 837.06 (253.25) | 641.23 (195.83) | −195.84 (202.99) | 103.44–288.23 | ***0.001*** | 0.494 |
| | | $p_{group}$ | | *0.252* | *0.833* | *0.180* | | | |
| | CE | SOG | 21 | 780.54 (201.71) | 657.78 (256.93) | −122.75 (292.89) | −10.57-256.07 | *0.069* | 0.156 |
| | | ISOG | 21 | 834.22 (258.39) | 708.17 (351.5) | −126.05 (299.67) | −10.36-262.46 | *0.068* | 0.157 |
| | | $p_{group}$ | | *0.457* | *0.599* | *0.971* | | | |
| Ellipse Surface ($mm^2$) | OE | SOG | 21 | 118.79 (99.75) | 255.97 (423.87) | +137.18 (421.74) | −329.16-54.79 | *0.152* | 0.100 |
| | | ISOG | 21 | 142.86 (170.38) | 198.64 (326.5) | +55.78 (214.77) | −153.54-41.98 | *0.248* | 0.066 |
| | | $p_{group}$ | | *0.579* | *0.248* | *0.435* | | | |
| | CE | SOG | 21 | 143.56 (172.52) | 101.19 (111.03) | −42.38 (157.7) | −29.41-114.16 | *0.232* | 0.070 |
| | | ISOG | 21 | 144.09 (273.28) | 135.88 (180.24) | −8.21 (265.98) | −112.86-129.29 | *0.889* | 0.001 |
| | | $p_{group}$ | | *0.994* | *0.457* | *0.615* | | | |
| Delta X (mm) | OE | SOG | 21 | 12.81 (5.73) | 18.88 (16.4) | +6.07 (15.88) | −13.3-1.16 | *0.095* | 0.133 |
| | | ISOG | 21 | 15.51 (14.82) | 15.12 (15.85) | −0.4 (6.1) | −2.38-3.17 | *0.768* | 0.004 |
| | | $p_{group}$ | | *0.095* | *0.768* | *0.089* | | | |
| | CE | SOG | 21 | 15.16 (11.12) | 13.16 (8.34) | −2 (8.85) | −2.03-6.03 | *0.312* | 0.051 |
| | | ISOG | 21 | 13.06 (10.57) | 14.67 (9.82) | +1.61 (10.41) | −6.35-3.13 | *0.486* | 0.025 |
| | | $p_{group}$ | | *0.533* | *0.594* | *0.232* | | | |
| Delta Y (mm) | OE | SOG | 21 | *13.81 (8.19)* | *14.17 (9.12)* | *+0.36 (9.7)* | −4.77-4.06 | *0.867* | 0.001 |
| | | ISOG | 21 | *12.95 (7.12)* | *15.12 (10.03)* | *+2.17 (8.7)* | −6.13-1.79 | *0.266* | 0.061 |
| | | $p_{group}$ | | *0.719* | *0.457* | *0.497* | | | |
| | CE | SOG | 21 | *13.28 (9.09)* | *12.06 (9.4)* | *−1.21 (11.83)* | −4.17-6.6 | *0.643* | 0.011 |
| | | ISOG | 21 | *13.33 (8.56)* | *14.3 (9.94)* | *+0.98 (8.6)* | −4.89-2.94 | *0.609* | 0.013 |
| | | $p_{group}$ | | *0.985* | *0.457* | *0.497* | | | |

Abbreviations: *p*group: Independent Means t-test; $p_{pair}$: Paired t-Test; $\eta_p^2$: Partial eta square; Effect size: small effect = 0.009, medium effect = 0.058, and large effect = 0.137; SOG: Control group using spinal orthosis; ISOG: Group using insoles with spinal orthosis; OE: Open Eyes; CE: Close Eyes; Delta X: oscillation in the mediolateral direction, Delta Y: oscillatory changes in the anteroposterior direction; Data expressed as mean (SD); $p < 0.05$ was considered to be significant; Bold values indicate that it is statistically significant ($p < 0.05$).

have a positive effect on PP and sagittal balance. Thus, the combined use of insoles with a spinal orthosis is recommended, in line with a previous study (Vasiliadis and Grivas, 2008).

The asymmetry in trunk posture observed in individuals with scoliosis negatively affects postural balance (Ma et al., 2020). Early spinal orthosis severely impacts postural balance (Wiernicka et al., 2019). Some studies have reported that long-term insoles and spinal orthoses use improve postural balance (Kavyani et al., 2020; Paolucci et al., 2013). Our study shows that a decrease in swing length improves postural balance, consistent with previous findings. These benefits may be attributed to the adaptation of spinal orthoses. The insole group exhibited a greater reduction in swing length and improved sensory input. However, no significant differences were observed in postural balance parameters except for swing length. Our experience suggests that results may change during long-term follow-up in our study.

Decreased FC in individuals with scoliosis is among the most important complications of scoliosis (Amaricai et al., 2020). In individuals with AIS, FC increased proportionally with the duration of spinal orthosis (Christovao et al., 2013). We found an increase in FC in both groups after 3 months of follow-up, consistent with previous research (Christovao et al., 2013). Insoles were observed to enhance FC (Haddas et al., 2021), and our study noted a greater increase in FC in the group that used insoles. Individuals who wear insoles may experience improved gait and enhanced sensory input from their feet.

**Table 5**
Descriptive statistics for, functional capacity and quality of life.

| | $N$ | Pre-test. Mean (SD) | Post-test. Mean (SD) | Within-group difference Mean (SD) | 95% CI for diff. | $P_{pair}$ | Effect size ($\eta_p^2$) |
|---|---|---|---|---|---|---|---|
| 6 MWT (m) | | | | | | | |
| SOG | 21 | 355.67 (72.35) | 368.0 (64.07) | +12.33 (44.65) | −32,66-7,99 | *0.220* | 0.074 |
| ISOG | 21 | 322.19 (46.75) | 351.43 (51.21) | +29.24 (42.21) | −48,45–10.02 | ***0.005*** | 0.335 |
| $p_{group}$ | | *0.083* | *0.360* | *0.215* | | | |
| SRS-22 questionnaire total score | | | | | | | |
| SOG | 21 | 4.13 (0.34) | 4.07 (0.36) | −0.06 (0.35) | −0,1-0,22 | *0.427* | 0.032 |
| ISOG | 21 | 3.89 (0.51) | 3.83 (0.52) | −0.06 (0.32) | −0.09-0,2 | *0.421* | 0.033 |
| $p_{group}$ | | *0.083* | *0.360* | *0.963* | | | |

Abbreviations: *p*group: Independent Means t-test; $p_{pair}$: Paired t-Test; $\eta_p^2$: Partial eta square; Effect size: small effect = 0.009, medium effect = 0.058, and large effect = 0.137; SOG: Control group using spinal orthosis; ISOG: Group using insoles with spinal orthosis; 6 MWT: 6 Minute Walk Test; SRS-22: Scoliosis Research Society-22; Data expressed as mean (SD); $p < 0.05$ was considered to be significant; Bold values indicate that it is statistically significant ($p < 0.05$).

Conservative treatment prevents curve progression and improves body appearance and QoL (Griffon et al., 2020). However, spinal orthoses have been reported to negatively affect the QoL of individuals with scoliosis (Negrini et al., 2006). We observed a decline in total QoL scores in both groups after 3 months of follow-up, consistent with previous findings (Misterska et al., 2019; Negrini et al., 2006). This decrease in the total score may be attributed to the psychological changes that adolescent undergo and the cosmetic impact of spinal orthoses.

## 5. Conclusion

Among individuals with AIS, the application of insoles with spinal orthosis decreased CA and positively affected static PP, postural balance, and FC, but it had no significant impact on QoL.

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## Declaration of Competing Interest

The authors have no conflicts of interest to declare.

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