Assessment of gait characteristics and orthotic management in children with Developmental Coordination Disorder: Preliminary findings to inform multidisciplinary care

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1. Introduction

Developmental Coordination Disorder (DCD) is a neurodevelopmental disorder characterised by impaired motor coordination and awkward gait. Despite self-reported findings of pes planus and joint hypermobility in children with DCD, there is little objective evidence regarding the clinical management of the foot in children with DCD. The aims of this research were to report clinical findings of foot posture and lower limb hypermobility in children with DCD and to evaluate the impact of foot orthoses on spatio-temporal gait parameters. Children with DCD were recruited into the study. Participants were randomly assigned to an intervention group who received foot orthoses at the start of their rehabilitation programme or to a second group who received foot orthoses at the end of their intervention programme. Foot posture was assessed with the Foot Posture Index and lower limb hypermobility assessed with the Lower Limb Assessment Score. The effect of foot orthoses was evaluated through assessment of spatio-temporal gait characteristics at baseline and post-rehabilitation programme. Fourteen children were recruited (mdn age 7.5 years) with nine children assigned to the group receiving orthoses early (mdn age 8 years) and five children assigned to the post-rehabilitation orthoses group (mdn age 6.5 years). A pes planus foot posture (FPI score = 8) and lower limb hypermobility (LLAS score = 11) were observed. Changes in spatio-temporal gait parameters failed to reach significance (p > .012) following orthotic invention but demonstrated a trend towards a decreased cadence and increased double support duration. Despite non-significant findings this work offers preliminary support for podiatric intervention in the rehabilitation of children with DCD. Further work is required to understand the biomechanics of gait in children with DCD and appreciate the role of podiatry as a component of multidisciplinary care.
in DCD. Rehabilitation for children with DCD requires a multidisciplinary approach underpinned by contemporary theories of human movement science (Polatajko & Cantin, 2006). Yet despite previous findings of flat feet and joint hypermobility (Kirby & Davies, 2006), there is little objective evidence regarding the clinical management of the foot in children with DCD.

It has been suggested that foot orthoses, as an addition to current management regimes for children with DCD, are warranted to address aberrant mechanics of the foot and lower limb that are associated with pes planus and joint hypermobility (Kirby & Davies, 2006). Foot orthoses are devices worn in the shoe which alter loading patterns during walking. Foot orthoses have been reported to prevent lower limb injury and reduce symptoms associated with soft tissue stress (Collins, Bisset, McPoil, & Vicenzino, 2007; Landorf & Keenan, 2000; Williams & Nester, 2010). In the paediatric context orthoses have also been reported to improve pain and disability in children with Juvenile Idiopathic Arthritis (Powell, Seid, & Szer, 2005). Nevertheless, recent conclusions from a Cochrane review (Rome, Ashford, & Evans, 2010) confirmed that further evidence was required to determine the efficacy of orthoses in the management of childhood conditions. Little is currently known about the clinical management of pes planus and joint hypermobility in children with DCD. The aims of this research were twofold: (1) to report clinical findings of foot posture and lower limb hypermobility in children with DCD and (2) to evaluate the impact of foot orthoses on spatio-temporal gait parameters.

2. Methods

2.1. Participants

Children with a diagnosis of DCD aged between 6 and 11 years of age referred to a Physical and Developmental Assessment rehabilitation programme within the Children’s Therapy Service at Medway Community Healthcare were considered for participation in the study. Children referred into this programme were entering a seven week programme designed to give children with DCD the opportunity to practice and experience success with skills they found difficult. This consisted of clinical input from occupational therapists (for visual motor integration, visual perception, and fine motor skill development), physiotherapists (for gross motor skill development, core stability and co-ordination) and podiatry (for foot assessment and foot orthoses). Prior to entry onto the programme participants were provided with study information. Parents of all children suitable for inclusion provided written consent and children were asked for assent prior to participation. Ethical approval was granted by the University of East London Research Ethics Committee and Lewisham Local Research Ethics Committee.

All children entering the standard rehabilitation programme were screened for inclusion. Children with any medical complications likely to affect gait beyond those typical of DCD were excluded from the study. This excluded any condition affecting neuromuscular integrity and/or orthopaedic conditions (such as Talipes Equino Varus) that might lead to a gait changes. Foot posture was screened prior to participation and those presenting with a Foot Posture Index (Redmond, Crosbie, & Ouvrier, 2006) score of greater than +4 (indicating a pronated foot type) were invited to participate. Although arbitrary this level of cut-off was chosen to exclude children who would not normally be considered for foot orthoses due to having a typical arch profile for age. The need to wear appropriate footwear was discussed with the family prior to inclusion and children unwilling to wear footwear suitable for use with an orthotic device (low heeled, fastening, supportive footwear) were also excluded from the study. All screening and measurements were conducted by the same clinician (SS).

Twenty two children were approached to participate in the study. All were male, white British and presented with foot posture scores greater than 4. Twenty children consented to participate in the study but five failed to attend the therapy session. One participant withdrew during the programme of research and fourteen participants (mdn age 7.5 years) progressed to completion of the study.

2.2. Classification of foot posture

Foot posture was evaluated with the Foot Posture Index (Redmond et al., 2006). This index had good reliability for assessment of the paediatric foot (Morrison & Ferrari, 2009) and was conducted with each participant standing barefoot. This measure involved assessment of (a) talar head palpation, (b) curvature at the lateral malleoli, (c) inversion/eversion of the calcaneus, (d) talonavicular bulging, (e) congruence of the medial longitudinal arch, and (f) ab/adduction of the forefoot on the rearfoot. A score between +2 to –2 was assigned for each measure creating a composite score ranging from +12 to –12.

2.3. Lower limb assessment score

The Lower Limb Assessment Score (LLAS) was used to measure lower limb hypermobility (Ferrari, Parslow, Lim, & Hayward, 2005). The LLAS is a 12 point score of each lower limb based upon assessment of (a) hip flexion, (b) hip abduction, (c) knee hyperextension, (d) knee anterior drawer test, (e) genicular rotation, (f) ankle joint dorsiflexion, (g) ankle joint anterior drawer, (h) subtalar joint inversion, (i) midtarsal joint inversion, (j) midtarsal joint abduction/adduction and dorsiplantarflexion, (k) 1st metatarsophalangeal joint dorsiflexion, and (l) weight bearing subtalar joint pronation. Each joint is scored one if the movement was excessive (based upon defined criteria) and a score of zero was assigned if not (Ferrari et al., 2005). Children...
scoring seven or above, out of a possible 12, were classified as hypermobile. This threshold was identified within the validation of the scoring system (Ferrari et al., 2005).

2.4. Six-minute walk test

All participants were asked to complete a Six-Minute Walk Test (American Thoracic Society, 2002). This required participants to walk continuously between two markers across a period of 6 min. The markers were set at a distance of 5 m apart and the total distance covered in the time was measured in metres. All participants were asked to walk unaided for the duration of the test and to cover as much distance as possible within the time. If a participant refused to start the test a score of zero was awarded.

2.5. Spatio-temporal gait parameters

The GAITRite walkway was used for the measurement of spatio-temporal gait parameters. A 4.5 m mat was placed in the centre of a walkway and each participant was instructed to walk across the mat to become comfortable with the procedure. Three trials were captured for each participant, with an average of five steps per trial. All children were instructed to walk in their normal style at a self-selected speed from 2 m before the mat and 2 m after the mat. All participants were instructed to look ahead at a point on the wall at the end of the room. Any footsteps which did not fall within the active sensor area of the mat were deleted and any trials with disruption to the typical gait pattern (e.g., tripping, walking in an unusual gait not considered typical by the parents) were deleted and the trial re-captured. Trials deemed by parents/guardians as a typical representation of their child’s normal gait were accepted. The primary outcome measures were cadence, stride length and double support duration, parameters reported to be reliable in children with DCD (Morrison, Ferrari, & Smillie, 2012). Baseline measurements were recorded with the participant in footwear. Review measurements were conducted with the participant in footwear and, where provided, orthoses.

2.6. Quasi randomisation

All participants entering the study were quasi-randomised into one of two groups using a sealed envelope technique. Each envelope was opened after the child consented to taking part in the programme and had completed their initial assessment so that the investigator remained blind to the treatment group during the initial data collection. Group one was comprised of children issued with their orthoses at the start of the rehabilitation programme and worn throughout. The second group were issued their orthoses at the end of the seven week rehabilitation programme.

2.7. Foot orthoses

Manufacture of foot orthoses commenced with both feet being captured in a controlled weight bearing sub-talar joint neutral position in a 55 mm deep foot impression foam box (Algeos foam impression box). Each participant was asked to stand upright in a natural angle and base of gait and raise one foot which was placed lightly on top of the foam box. The head of the talus was palpated and each participant was asked to weight bear through the heel whilst the researcher controlled the position and applied pressure to assist weight bearing of forefoot and toes. All casts were filled with Plaster of Paris and the cast was further modified with a 6 mm medial heel skive. All orthoses were manufactured with a 25 mm deep heel cup manufactured from 4 mm Madrilen thermoplastic. A high density Ethyl Vinyl Acetate heel stabiliser was added and all devices were issued within two weeks of casting.

Nine children were assigned to group one (mdn 8 years) and five children were assigned to group two (mdn age 6.5 years) and received their orthoses after the rehabilitation programme.

2.8. Statistical analysis

Non-parametric tests were utilised for statistical analysis. To test for differences between the groups at baseline and seven week follow-up for primary (cadence, stride length and double support duration) and secondary (six minute walk test) outcome measures the Mann–Whitney U test was used. Bonferroni correction was applied due to multiple comparisons being undertaken. The level of significance was \( p \leq .012 \) after correction. All statistical analyses were performed using IBM SPSS statistics software (Version 20).

3. Results

Median FPI-6 score for both feet was 8 and median scores for both limbs were 11. Both groups were similar for age, foot posture and hypermobility score.

There were no significant differences between gait characteristics for the two groups (see Table 1) at baseline (cadence: \( U = 30, p = .36 \); stride length: \( U = 13, p = .24 \); or double support duration: \( U = 9, p = .08 \)). At seven week follow-up no significant differences between the groups were observed for cadence (\( U = 5, p = .019, r = −0.60 \)), double support duration (\( U = 7, p = .10 \)),
DCD have a flat-foot type (Kirby & Davies, 2006) and re-iterates the need for provision of appropriate intervention for these flatfoot which is classified as a range of 10–12. The findings are consistent with previous observations that children with DCD. Values for foot posture confirmed that children had a pronated foot position during standing, but not a severely utilising reliable and objective clinical measures this study has reported characteristics of the foot and lower limb in children traversed at follow up. Medium effect sizes were reported for stride length ($r = 0.58$) or stride length ($U = 24, p = .23, r = 0.32$). The six-minute walk test did not differ significantly between the groups at baseline ($U = 29, p = .43, r = 0.27$) although both groups showed an increased distance traversed at follow up. Medium effect sizes were reported for stride length ($r > 0.3$) and large effect sizes reported for cadence and double support duration ($r > 0.5$).

### 4. Discussion

The aim of this study was to report clinical findings of foot posture and lower limb hypermobility in children with DCD. We also sought to evaluate the impact of foot orthoses on spatio-temporal gait parameters in children with DCD. Through utilising reliable and objective clinical measures this study has reported characteristics of the foot and lower limb in children with DCD. Values for foot posture confirmed that children had a pronated foot position during standing, but not a severely flat foot which is classified as a range of 10–12. The findings are consistent with previous observations that children with DCD have a flat-foot type (Kirby & Davies, 2006) and re-iterates the need for provision of appropriate intervention for these children (Kirby & Davies, 2006). Further indication for this intervention is the symptomatology typical of DCD which includes poor balance and fatigue. Consideration of this finding is warranted because pes planus has been reported to influence motor performance (Benedetti et al., 2011) and may contribute to the development of musculoskeletal pathology (Lin, Lai, Kuan, & Chou, 2001).

Children have greater joint mobility than adults and hypermobility is often observed (Murray, 2006). In a study comparing assessment scores for the LLAS within a sample of typically developing children, Ferrari et al. (2005) reported a cut-off value of 7/12. Mean scores in our sample of children were 11 for both limbs which suggested that children with DCD were at the top end of the scale for lower limb hypermobility. This finding is interesting because hypermobility has been associated with abnormal foot posture (Ross & Shore, 2011) and may exacerbate poor coordination during dynamic activities. Further work exploring the association between foot posture, function and hypermobility is required.

Following seven-week orthotic intervention no significant differences between the two groups for spatio-temporal gait or six-minute walk test were found. Participants who received their orthoses at the start of the study had a small reduction in cadence compared with the non-intervention group who demonstrated an increase (see Table 1). This finding was near significance and demonstrated a large effect size. A high cadence is characteristic of an unstable gait and this difference could suggest that foot orthoses were beneficial in supporting stability during gait. Our data also demonstrated an increase in double support duration when wearing orthoses despite failing to reach significance. The gait pattern of children with DCD is rapid, unstable and typically associated with reduced double support duration (Deconinck et al., 2006). The small increase reported in this study may suggest that orthotic intervention was beneficial for enhancing stability during gait leading to improved joint kinematics during the stance phase of gait leading to a more stable and consistent gait pattern. Of note, the use of an instrumented walkway limits the interpretation of these findings and further investigation of joint kinematics and kinetics throughout gait is required.

The challenges with characterising gait patterns in children with DCD have previously been reported (Morrison et al., 2012) and must be acknowledged as a limitation of this study. Despite the randomisation of the two groups it is impossible to rule out the contributions of the therapy programme to the improvements seen and further work on this is warranted. The sample of children recruited into the study was small and the analysis statistically underpowered. This increases the likelihood of type II error and limits the external validity of the work. Further work is needed to explore the role of foot orthoses in children with DCD and further consideration of the mechanics of the foot in children with DCD is required to inform management strategies and to ensure foot function is optimised during gait. Patient-centred outcomes may also be beneficial to include in future studies as we received many reports that the orthoses had been useful and would continue to be worn after the study ended, but the lack of a validated patient-outcome scoring system for use with orthoses prevented the inclusion of this data.

### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Median (IQR) baseline</th>
<th>Median (IQR) post-intervention</th>
<th>Significance $p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadence (steps/min)</td>
<td>1</td>
<td>115.4 (112–130)</td>
<td>114.7 (108.6–124.9)</td>
<td>$p = .019$</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>126.2 (117.5–135.7)</td>
<td>131.9 (123.8–145)</td>
<td></td>
</tr>
<tr>
<td>Stride (m)</td>
<td>1</td>
<td>108 (103.7–18.2)</td>
<td>107.5 (102.2–122.3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>102 (98–113.1)</td>
<td>102 (95.2–111.9)</td>
<td>$p = .23$</td>
</tr>
<tr>
<td>Double support (%)</td>
<td>1</td>
<td>23 (22–25)</td>
<td>25 (21.7–26.9)</td>
<td>$p = .042$</td>
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<tr>
<td></td>
<td>2</td>
<td>21.1 (19.5–22.7)</td>
<td>21.5 (19.3–22.3)</td>
<td></td>
</tr>
<tr>
<td>6 min walk test (m)</td>
<td>1</td>
<td>347 (321–383)</td>
<td>351 (312.5–433.25)</td>
<td>$p = .43$</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>375 (0–428)</td>
<td>390 (375.5–437)</td>
<td></td>
</tr>
</tbody>
</table>

* Significance level .012 after Bonferroni correction.

Group 1 received orthoses at the start of the study and group 2 received orthoses after study completion.
5. Conclusion

Through application of objective clinical measures this study has confirmed a pes planus foot posture and hypermobility of the lower limb in children with DCD. Findings from this research offer preliminary evidence of changes in spatio-temporal gait parameters following orthotic invention despite failing to reach significance. The trend in the data offers preliminary support for podiatric intervention in children with DCD. Further work is required to understand the characteristics of gait and foot function in DCD and appreciate the role of podiatry within multidisciplinary care.

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References