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Research Paper

The effect of asymmetrical limited hip flexion on seating posture, scoliosis and windswept hip distortion

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ABSTRACT

Background: Postural asymmetries with seating problems are common in adults with cerebral palsy.
Aims: To analyse the prevalence of asymmetrical limited hip flexion (< 90°) in adults with CP, and to evaluate the association between asymmetrical limited hip flexion and postural asymmetries in the sitting position.
Methods and procedures: Cross-sectional data of 714 adults with CP, 16–73 years, GMFCS level I–V, reported to CPUP, the Swedish cerebral palsy national surveillance program and quality registry, from 2013 to 2015. Hip range of motion was analysed in relation to pelvic obliquity, trunk asymmetry, weight distribution, scoliosis and windswept hip distortion.
Outcomes and results: The prevalence of asymmetrical limited hip flexion increased as GMFCS level decreased. Of adults at GMFCS level V, 22% had asymmetrical limited hip flexion (< 90°). The odds of having an oblique pelvis (OR 2.6, 95% CI:1.6–2.1), an asymmetrical trunk (OR 2.1, 95% CI:1.1–4.2), scoliosis (OR 3.7, 95% CI:1.3–9.7), and windswept hip distortion (OR 2.6, 95% CI:1.2–5.4) were higher for adults with asymmetrical limited hip flexion compared with those with bilateral hip flexion > 90°.
Conclusions and implications: Asymmetrical limited hip flexion affects the seating posture and is associated with scoliosis and windswept hip distortion.

What this paper adds?

This paper contributes to the field of seating analysis for individuals in wheelchairs. It shows that asymmetrical limited hip flexion (< 90°) is present in about 22% of individuals with cerebral palsy who are classified at GMFCS level V. It confirms that the presence of asymmetrical limited hip flexion (< 90°), increases the odds of pelvic obliquity, trunk asymmetry, scoliosis, and windswept hip distortion. Therefore, asymmetrical limited hip flexion needs to be ruled out or compensated, especially in individuals with spastic bilateral CP at GMFCS level V, who are in a poor seating posture.

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1. Introduction

1.1. Cerebral palsy

Cerebral palsy is a well-recognised neurodevelopmental condition that manifests in early childhood and persists throughout life (Rosenbaum et al., 2007). It has been attributed to a non-progressive disturbance that occurs in the developing fetal or infant brain. Cerebral palsy is the most common physical disability in childhood, with a prevalence of 2–2.4/1000 live births in Europe (Nordmark, Hägglund, & Lagergren, 2001; SCPE, 2002). In Sweden, the survival rate to 20 years of age is 60% among the most severely disabled children with cerebral palsy (Westbom, Bergstrand, Wagner, & Nordmark, 2011), although the survival rate in Britain is lower (Hutton & Pharoah, 2006).

1.2. Contractures and asymmetries

The term “joint contractures” is used to describe the loss of passive range of movement in diarthrodial joints (Wong, Trudel, & Laneuville, 2015). Long-lasting reduction of spasticity does not prevent contracture development (Tedroff, Lowing, Jacobson, & Astrom, 2011), and in pure immobilisation, the role of arthrogenic structures in contracture development increases with time, in such a way that immobilisation in flexion leads to limited extension but allows more flexion (Trudel & Uhthoff, 2000). Pope (Pope, 2007) described the effect of sitting with asymmetrical limited hip flexion ($< 90°$), where the ipsilateral side of the pelvis will go up and in a forward direction, directing the trunk to the contralateral side. Lateral spinal curvature is needed to compensate for the asymmetry caused by pelvic obliquity (Porter, Michael, & Kirkwood, 2007). In adults with cerebral palsy who have lower levels of motor function, more postural asymmetries are present in the sitting position than when standing, and these asymmetries are associated with a limited range of motion, scoliosis, and the inability to change position (Rodby-Bousquet, Czuba, Hägglund, & Westbom, 2013).

1.3. Aim

The aim of this study was to analyse the prevalence of asymmetrical limited hip flexion less than 90° (ALHF $< 90°$) in individuals with cerebral palsy and to evaluate the association between ALHF $< 90°$ and asymmetrical seating posture, the occurrence of scoliosis, and windswept hip distortion.

2. Methods

2.1. Ethical approval and consent

Ethical approval was granted by the Medical Research Ethics Committee at Lund University (LU 2009-341), and permission was obtained to extract data from the CPUP registry. All participants consent to research based on reported data. No individual details are presented.

2.2. Data collection and participants

This cross-sectional study was performed based on data from the national surveillance program and quality registry for cerebral palsy in Sweden (CPUP) (Alriksson-Schmidt et al., 2017). Data were extracted from the most recent reports for all adults with cerebral palsy included in the registry between 1st of January 2013 and 31st of December 2015. Inclusion and exclusion criteria were defined by the Surveillance of Cerebral Palsy in Europe (SCPE, 2002), and subtypes were classified into spastic unilateral, spastic bilateral, ataxic, and dyskinetic cerebral palsy. A total of 714 adults comprising 357 men and 357 women with a median age of 23 years (range 16–73 years) were reported to the CPUP registry. The subjects' gross motor function ranged from GMFCS level I ($n = 159$), II ($n = 150$), III ($n = 114$), IV ($n = 122$) to level V ($n = 170$) (Table 1). The distribution of participants' neurological subtypes was as follows: spastic unilateral ($n = 156$), spastic bilateral ($n = 385$), ataxic ($n = 25$), dyskinetic ($n = 92$), and mixed or unclassified subtypes ($n = 42$). Subtypes were not reported for 14 adults.

2.3. Classifications and measurements

All assessments were performed by local physiotherapists and occupational therapists in a standardised manner employing an assessment form and an accompanying manual (www.cpup.se).

2.3.1. Gross motor function classification system

Gross motor function was classified using the expanded and revised version of the Gross Motor Function Classification System (GMFCS) levels I–V, age band 12–18 years (Palisano, Rosenbaum, Bartlett, & Livingston, 2008). Even though GMFCS was developed for children, it has also been shown to be accurate for use in adults with cerebral palsy (Jahnsen, Aamodt, & Rosenbaum, 2006; McCormick et al., 2007).

Table 1
Numbers and percentages of the 714 individuals with distribution of the GMFCS levels, asymmetrical limited hip flexion, and items from the Posture and Postural Ability Scale (trunk, pelvis, and weight distribution) in sitting, direction of scoliosis, and windswept hip distortion as well as complete data for each variable.

	Complete data set	Gross Motor Function Classification System Level					
		I N = 159	II N = 150	III N = 114	IV N = 121	V N = 170	Total 714
ALHF < 90°[a]	N = 665 (93%)	2 (1%)	5 (3%)	7 (6%)	11 (9%)	38 (22%)	63 (9%)
Asymmetrical trunk	N = 672 (94%)	24 (15%)	31 (21%)	41 (36%)	60 (50%)	96 (56%)	252 (35%)
Oblique pelvis	N = 672 (94%)	24 (15%)	31 (21%)	41 (36%)	60 (50%)	96 (56%)	252 (35%)
Uneven weight distribution	N = 661 (93%)	15 (9%)	32 (21%)	39 (34%)	64 (53%)	99 (58%)	249 (15%)
Scoliosis[b]	N = 286 (40%)	2 (1%)	5 (3%)	10 (9%)	16 (13%)	60 (35%)	93 (13%)
Convex right		1 (1%)	3 (2%)	5 (4%)	6 (5%)	34 (20%)	49 (7%)
Convex left		1 (1%)	2 (1%)	5 (4%)	10 (8%)	26 (15%)	44 (6%)
Windswept hip distortion[c]	N = 336 (47%)	14 (9%)	31 (21%)	26 (23%)	32 (26%)	60 (35%)	163 (25%)
To the right		9 (6%)	17 (11%)	12 (11%)	17 (14%)	36 (21%)	91 (13%)
To the left		5 (3%)	14 (9%)	14 (12%)	15 (12%)	24 (14%)	72 (10%)

[a] Asymmetrical limited hip flexion (ALHF < 90°): including those with no missing hip flexion value.
[b] Scoliosis: including those with moderate and severe scoliosis.
[c] Windswept hip: distortion including those with no missing values for hip abduction or internal and external rotation.

2.3.2. Posture and postural ability scale

Seated posture was assessed using items from the Posture and Postural Ability Scale (PPAS) (Rodby-Bousquet et al., 2014), which has high psychometric properties for adults with cerebral palsy (Rodby-Bousquet et al., 2014). The items that were used were neutral pelvis, symmetrical trunk, and even weight distribution. Symmetry was noted as yes, and asymmetry was noted as no. In the CPUP registry, scoliosis was rated as no scoliosis, mild, moderate, or severe using a clinical spinal examination that has high psychometric properties for neuromuscular scoliosis in individuals with cerebral palsy (Persson-Bunke, Czuba, Hägglund, & Rodby-Bousquet, 2015). In this study, mild or no scoliosis was treated as not having scoliosis. Individuals operated for scoliosis were included in the study. If they were reported to have a remaining moderate or severe scoliosis after surgery they were included in the scoliosis group, if not, they were treated as not having a scoliosis. The direction of the lowest lateral curve of scoliosis was noted. Those with missing values for either the degree or the direction of scoliosis were excluded.

2.3.3. Range of motion

Passive joint range of movement for hip flexion, abduction, and external and internal rotation were measured with a goniometer in a standardised supine position according to the manual. Asymmetrical limited hip flexion was defined as a range of hip movement that did not exceed 90° of hip flexion and was reduced by at least 5° compared with the contralateral side. The selection of 5° difference was based on results from Boone et al. (1978).

2.3.4. Windswept hip distortion

The windswept hip distortion consists of abduction and external rotation of one hip, with the opposite hip in adduction and internal rotation. The presence of windswept hip distortion was confirmed by using Persson–Bunke's method (Persson-Bunke, Hägglund, & Lauge-Pedersen, 2006) and the direction of the windswept distortion was confirmed by using modified version of Porters method (Porter et al., 2007). Both methods are modified from Young's work (Young et al., 1998). Those who were not windswept according to both methods were determined not windswept. In Persson-Bunkes method at least 50% difference were needed to be between right and left side in either: hip abduction, hip internal or hip external rotation, to define the presence of windswept hip distortion. Values lower than 0.5 or higher than 2, were considered windswept. In Porters modified version the hip range of movement (hip abduction, hip external rotation and hip internal rotation on each side were added together. Then left side were subtracted from the right side. Threshold value was 20°, plus value 20° or higher indicated windswept over to the right and a negative value −20° or lower indicated windswept over to the left. Hip internal rotation is in opposite direction to hip abduction and hip external rotation and has therefore a minus value. Values for each side are added together.

2.4. Statistical analyses

The chi-square (χ^2) test, a nonparametric test, was used to analyse the relationship between variables. The significance level was set at $p < 0.05$. Logistic regression was used to estimate the association between ALHF < 90° and the GMFCS levels, postural asymmetries in sitting, scoliosis, windswept hip distortion, the direction of lateral spinal curvature caused by scoliosis, and the direction of windswept hip distortion. The results were presented as odds ratios (OR), which are ratios between two odds and express the probability that an event will occur, with 95% confidence intervals (95% CI). SAS Enterprise Guide 7.11 was used for the statistical analyses (SAS Institute Inc., Cary, NC, USA).

Table 2
Percentage of individuals with more than 90° bilateral hip flexion or asymmetrical limited hip flexion, relative to asymmetrical trunk, oblique pelvis, uneven weight distribution, scoliosis, and windswept hip distortion.

	Complete data set	> 90° bilateral hip flexion	Asymmetrical limited hip flexion (< 90°)	Chi square test
Asymmetrical trunk	N = 631	211 (37%) N = 577	39 (72%) N = 54	$p < 0.001$
Oblique pelvis	N = 621	199 (35%) N = 566	40 (72%) N = 55	$p < 0.001$
Uneven weight distribution	N = 629	200 (35%) N = 574	36 (65%) N = 55	$p < 0.001$
Scoliosis	N = 286	67 (26%) N = 257	21 (72%) N = 29	$p = 0.019$
Windswept hip distortion	N = 336	81 (27%) N = 302	19 (56%) N = 34	$p < 0.001$

The percentage of individuals, within each group, who have an oblique pelvis, an asymmetrical trunk, a scoliosis, and a windswept hip distortion.
Total number of individuals who have an oblique pelvis, asymmetrical trunk, moderate or severe scoliosis, or windswept hip distortion, and information about the hip flexion range of movement are available.

3. Results

3.1. Prevalence of asymmetrical limited hip flexion

A clear escalation of asymmetries was seen with increasing GMFCS level (Table 1); i.e., they became more frequent as function decreased. Hip flexion was reported for 665 individuals, 63 of whom (9%) had ALHF < 90°. Seven individuals had symmetrical limited hip flexion (i.e. < 90° of hip flexion on both sides) and were excluded from the analyses. Of the 172 individuals younger than 20 years of age, four (2%) had an asymmetric limited hip flexion, versus 9% in the total group. No one under the age of 19 years (n = 113) had ALHF < 90°. The majority of individuals with asymmetrical limited hip flexion were classified at GMFCS level V (60%), and the right hip (n = 39) was more often limited than the left hip (n = 24). All individuals were included in the analyses, independent of their GMFCS level. A majority of the individuals for whom hip flexion values were missing in the registry were at GMFCS level V. Of the individuals with ALHF < 90°, 49 (78%) were classified as having spastic bilateral cerebral palsy, and five (8%) were classified as having spastic unilateral cerebral palsy. Values for calculation of windswept hip distortion: abduction, and internal and external rotation were reported for 336 individuals; the majority of missing values were for adults at functional level V.

3.2. Asymmetrical limited hip flexion and postural asymmetries

More individuals with ALHF < 90° had an oblique pelvis, an asymmetrical trunk, an uneven weight distribution, scoliosis, and a windswept hip distortion (Table 2) compared with those who had bilateral hip flexion > 90°. No association was found between the side of limited hip flexion and either the direction of convexity of the lower scoliotic curve ($p = 0.808$) or the windswept hip distortion ($p = 0.273$). Of those subjects with limited right hip flexion, the direction of convexity of the lower scoliotic curve was to the right in six and to the left in six. Of those subjects with limited left hip flexion, the direction of convexity of the lower scoliotic curve was to the right in five and to the left in four. The odds of having an ALHF < 90° were higher (OR 2.2, 95% CI: 1.7–2.8) for each GMFCS level compared with that for the functional level above. The odds of pelvic obliquity, trunk asymmetry, uneven weight distribution, scoliosis, and windswept hips in sitting were almost four times higher for adults with ALHF < 90° compared with those who had bilateral hip flexion > 90° (Table 3). After adjustment for GMFCS level, the odds of having an oblique pelvis, an asymmetrical trunk, a scoliosis, and windswept hip distortion were still significantly higher for those with ALHF < 90° compared with those who had bilateral hip flexion > 90° (Table 3).

4. Discussion

There was a clear association between ALHF < 90° and an asymmetric sitting posture, scoliosis, and windswept hip distortion in adults with cerebral palsy. ALHF < 90° was more frequent in adults with spastic bilateral cerebral palsy (78%) and at lower levels of motor function (level V).

Table 3
Odds Ratio (OR) for effect from asymmetrical limited hip flexion and the Gross Motor Function Classification System (GMFCS) score on items from PPAS (trunk, pelvis, and weight) in sitting, scoliosis, and windswept hip distortion.

Dependent variable	GMFCS	Asymmetrical limited hip flexion	Asymmetrical limited hip flexion adjusted for GMFCS
Asymmetrical trunk	1.9 (1.8–2.4)[a]	4.5 (2.4–8.4)[a]	2.1 (1.1–4.2)[a]
Oblique pelvis	1.9 (1.7–2.2)[a]	4.9 (2.7–9.1)[a]	2.6 (1.6–2.1)[a]
Uneven weight distribution	2.2 (1.9–2.5)[a]	3.5 (2.0–6.3)[a]	1.5 (0.8–2.9)
Scoliosis	2.8 (2,2–3.7)[a]	7.4 (3.1–17.6)[a]	3.7 (1.3–9.7)[a]
Windswept hip distortion	1.5 (1.3–1.8)[a]	3.5 (1.7–7.1)[a]	2.6 (1.2–5.4)[a]

The interaction between the GMFCS score and asymmetrical limited hip flexion was not significant.
[a] Significant predictor $p < 0.05$.

The odds were higher of having an oblique pelvis and asymmetrical trunk in those individuals who had ALHF < 90° than in those with bilateral hip flexion > 90°. The results support Pope's (Pope, 2007) theory that ALHF < 90° is associated with an oblique pelvis and an asymmetry in the trunk. Furthermore, it supports Porter's (Porter et al., 2007) hypothesis that lateral curvature of the spine is needed to straighten up the trunk. Individuals with a spinal fusion, cannot straighten up the trunk and will lean to the side while sitting, if ALHF < 90°, has not been compensated for in the seating system. Depending on the level of the fusion, they have a tendency to compensate this with a lateral flexion of the cervical spine. Therefore it is essential to accommodate the seating system for any restricted hip motion in order to align the posture.

The fact that 22% of individuals at GMFCS level V had ALHF < 90° might explain Rodby-Bousquet's (Rodby-Bousquet et al., 2013) unexpected findings that adults with cerebral palsy who had lower levels of motor function had more postural asymmetries present in the sitting position than when standing. However, in either case, postural support is necessary. ALHF < 90° is easily overlooked in the sitting position, because it may be compensated for by mobility in the pelvis and the spine, causing an oblique pelvis and an asymmetrical trunk. Limited hip flexion has no effect on standing posture; therefore, it will not enhance any postural asymmetries while standing.

The pelvis is the anatomical structure that is directly linked to the hip joint and can therefore be expected to be most affected by ALHF < 90° in the sitting position. From a purely biomechanical aspect, it can be speculated that ALHF < 90°, when present, is the main contributor to the development of an ipsilateral higher side of the pelvis (Pope, 2007). According to Letts (Letts, Shapiro, Mulder, & Klassen, 1984), there is a clear association between total hip dislocation and the ipsilateral high side in oblique pelvis, but this effect has not been demonstrated for a subluxated hip (Porter et al., 2007).

Previous studies have suggested that in one-fourth of cases, the windswept hip distortion originates from the spine rather than the hips (Hägglund, Lauge-Pedersen, Bunke, & Rodby-Bousquet, 2016; Letts et al., 1984), but the presence of ALHF < 90° as a causative factor of oblique pelvis was not eliminated in those studies.

ALHF < 90° does not show the typical contracture pattern because the hip would need to be immobilised in extension to result in limited hip flexion (Trudel & Uhthoff, 2000). A majority of those with ALHF < 90° were individuals with bilateral spastic cerebral palsy at GMFCS levels IV and V. These are the individuals expected to have little or no postural ability, which can cause a slumped seating posture with a posteriorly tilted pelvis leading to an open hip joint angle. Their inability to resist the effect of gravity will usually require additional support in the seating system to maintain an aligned posture.

The direction of windswept hip distortion was independent of the side of limited hip flexion, but, consistent with previous findings (Persson-Bunke et al., 2006), the highest number of individuals with windswept hip distortion were classified at GMFCS level V. Coxa valga is often seen in spastic hips, and the proportion of valgus-deformed proximal femoral epiphyses increases as GMFCS level decreases (Lee et al., 2010). It can be speculated that the hip joint accommodates deteriorating forces from spasticity and lack of hip extension because of prolonged periods spent sitting and lying, resulting in limited hip flexion movement.

There were several limitations to this study. The majority of participants with missing values for the calculation of limited hip flexion and windswept hip distortion were at GMFCS level V; over 50% had missing values for the windswept hip calculation. The reason for these missing values is likely the fact that individuals at GMFCS level V have more severe contractures and distortion of body parts, resulting in difficulties in performing an appropriate range of movement for measurements. Because a majority of the individuals in this study with asymmetrical limited hip flexion were at GMFCS level V, the number with ALHF < 90° and windswept hips was most likely underestimated. No hip radiographs or information about the direction of the oblique pelvis, windswept hips, or primary curvature was available. This limited the possibility of estimating the causal effect of asymmetrical limited hip flexion.

Further studies investigating the combined factors that limit hip flexion movement and the causal factors for the high side in oblique pelvis are required. From the above, it can be concluded that ALHF < 90° greatly affects the parameters of the seating posture (pelvis and trunk) and is associated with scoliosis and windswept hip distortion. No association was found between the side of ALHF < 90° and the direction of the lowest scoliotic curve or the direction of windswept hip distortion. The fact that individuals younger than 20 years are less likely to have ALHF < 90°, indicates that ALHF < 90° either develops after 20 years of age, or that younger individuals receive more appropriate interventions to maintain range of motion.

5. Conclusions

Individuals with cerebral palsy, who has asymmetrical limited hip flexion < 90°, are likely to be spastic bilateral at GMFCS level V. The odds of pelvic obliquity, trunk asymmetry, scoliosis, and windswept hip distortion in adults with ALHF are higher than in those with bilateral hip flexion exceeding 90°. Oblique pelvis, asymmetric trunk, scoliosis, and windswept hip distortion are clinical signs of detrimental seating posture. ALHF need to be ruled out or compensated, especially in individuals with spastic bilateral CP at GMFCS level V, who are in a poor seating posture.

Competing interests

The authors declare that they have no competing interests.

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