Static balance in children with hand–eye co-ordination problems

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Abstract

Objective The aim of the present study was to examine static balance on one leg in 10-year-old children with and without hand–eye co-ordination problems (HECP) in an attempt to come closer to an understanding of developmental co-ordination disorder in children.

Method The children were compared on three different balance tasks with the right and/or left leg together with a systematic manipulation of vision.

Results The results showed that when the scores for both legs were combined, the control group, in general, had superior performance in all conditions. Separate preferred and non-preferred leg analyses demonstrated that the differences between the HECP group and control group could be accounted for by lowered performances when the non-preferred leg was used in only one static balance task, stork stand with vision. In the two other balance tasks, balance on beam and one-board balance, the HECP group displayed significantly worse performance than the control group irrespective of the use of the preferred or non-preferred leg.

Conclusions Explanation related to the development of the hemispheres controlling the preferred and non-preferred leg is invoked to account for the poor performance in the HECP group.

Keywords
developmental co-ordination disorders, hand–eye co-ordination problem, sensory integration, static balance, hemispheric development

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Introduction

The ability to co-ordinate the motor system is considered a prerequisite for skilled performance in many everyday life activities. This is particularly important for young children as their activities mostly consist of physical play and sport (Sigmundsson *et al.* 1997a). Some of these children, however, have documented problems when it comes to their ability to co-ordinate their movements. The issue of restricted motor competence (motor impairment) is an interesting phenomenon in its own right, but also because of a potential link to other socially related problems.

Children who have normal intelligence and are free of neurological disease yet who lack the motor co-ordination necessary to perform age-appropriate motor tasks have been described in the literature as motor impaired (Whiting *et al.* 1969), developmental apraxic and agnosic (Gubbay 1975), motorically awkward (Williams *et al.* 1983) and as having developmental dyspraxia (Dewey 1995). The most familiar term is 'clumsy', a term first used by Orton (1937) and since adopted by a number of authors (Gubbay 1975; Hulme & Lord 1986; Smyth 1992). Increasingly, however, the term developmental co-ordination disorder (DCD) (APA 1994) has been used.

Prevalence estimates range from 5 to 15% (Gubbay 1975; Henderson & Hall 1982). The figure 6% quoted in DSM-3 seems to be in line with estimates of prevalence made in Norwegian school age children (Søvik & Mæland 1986; Sigmundsson *et al.* 1997a, 1999a).

In order to accurately identify children with motor co-ordination difficulties, and to design effective intervention programmes that may improve their skills, it is important that the diagnosis and estimate of severity of motor problems should be detected at an early age. However, the construct of DCD has not been sufficiently described. Multiple factors (e.g. sensory skills, motor skills) may contribute to the deficit. Whereas a number of standardized test batteries have been developed to assess children's development in particular domains of sensorimotor function, no single test has been accepted for the diagnosis of DCD. Sigmundsson *et al.* (1997a) suggested that this might be owing to the fact that most tests lack the sensitivity to pinpoint the underlying neurological mechanisms of the motor deficits.

In the literature, there is universal agreement that children who are clumsy do not constitute a homogeneous group (Søvik & Mæland 1986; Henderson & Sugden 1992; Sigmundsson *et al.* 1997a). It would therefore seem much more meaningful and productive to focus on more clearly defined subgroups of children exhibiting clumsy behaviour and, at the same time, to go beyond the level of description to more explanatory frameworks. With this in mind, Sigmundsson and co-workers in a series of related studies turned their attention to a specific subcategory of clumsy children attending normal schools, namely those exhibiting hand–eye co-ordination problems (HECP).[1] Using a paradigm that von Hofsten and Rösblad (1988) used originally with normal children, these authors investigated how right-handed children with HECP and control children performed a manual matching task (Sigmundsson *et al.* 1997a,b, 1999a).[2] This task required targets on the surface of a specially designed table to be located visually (seen target), proprioceptively (felt) or in a combination (felt and seen). Analyses of the scores demonstrated that differences between the HECP children and the controls could mainly be accounted for by lowered performance when the non-preferred left hand was used to match the position of the located targets. It was suggested that these findings indicated a right hemisphere insufficiency (Geschwind 1975; Faglioni & Basso 1985; Heilman & Rothi 1993) with or without a dysfunctional corpus callosum, which, in turn, might be attributable to slow maturation (Trevarthen 1974; Galin *et al.* 1977; O'Leary 1980; Quinn & Geffen 1986; Zaidel 1998) or an interruption of transcallosal interhemispheric communication (Bogen 1993). Similar left–right differences were found in a study using foot–hand matching task (Sigmundsson *et al.* 1999a).

In a study by Estil *et al.* (2003) involving manual dexterity and static balance, children with language impairment between the ages of 5 and 10 years were assessed on two tests: the Illinois Test of Psycholinguistic Ability (Kirk *et al.* 1968) and the Movement Assessment Battery for Children (Movement ABC test) (Henderson & Sugden 1992). Results of the static balance test (the stork stand from the Movement ABC test) showed that when each leg was measured separately (all children's preferred leg was the right leg), the group with both language and motor impairment ($n = 4$) experienced more problems with balancing on the left than on the right leg.

The results from the studies above support the theory of Sigmundsson *et al.* (1997a,b) and Sigmundsson (1999) that right hemisphere insufficiency may be related not only to left hand/arm but also to the foot and left part of the body as well.

There is a general agreement that ability to control static or dynamic balance is an important component in the everyday life of children (Woollacott *et al.* 1987). Over the last couple of decades, research into postural and balance control and

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[1] The score on the hand–eye co-ordination subtests of the Movement Assessment Battery for Children test for the HECP showed a mean of 11.3, SD 2.49 and range 8–17. On the basis of the norms for these subtests alone, a score of 7.5 would place the child at the 15th percentile and a score greater than 11.5 at the 5th percentile.

[2] In the literature, there is universal agreement that children who are clumsy do not constitute a homogeneous group (Sigmundsson *et al.* 1997a). It would, therefore, seem much more meaningful and productive to focus on more clearly defined subgroups of children exhibiting clumsy behaviour.

their disorders has shifted and broadened (Shumway-Cook & Woollacott 1995). Balance is a complex task, and measurements are often related to a specific task or situation. Postural abnormalities could contribute to the delays and impairments seen in the child with motor problems. Development of balance control continues through at least 10 years of age (Forssberg & Nashner 1982; Berger *et al*. 1985; Shumway-Cook & Woollacott 1995). By 7–10 years of age, postural response are basically like those of the adults.

Many studies have identified measures of lower limb control as effective discriminators of clumsiness (Gubbay *et al*. 1965; Illingworth 1968; Reuben & Bakwin 1968; Dare & Gordon 1970; Lesny 1980; Shaw *et al*. 1982; Hulme *et al*. 1983; Heilman & Rothi 1993). These studies, and others of a similar nature, indicate that clumsiness in static balance is often seen in the child labelled as clumsy. Henderson and Hall (1982) found in their investigation of clumsy children that the simple test of how long children could balance on one leg without being able to make compensatory movements with the arms discriminated clumsy children from controls as well as or better than the tests of complex manual skill.

For a given task and environment, the child must determine the validity of a given sensory input for postural control, and then select the most appropriate one for the context (Shumway-Cook & Woollacott 1985). This involves organizing, integrating, and acting upon redundant visual, vestibular and proprioceptive inputs providing orientational information to the postural control system (Shumway-Cook & Woollacott 1985). Confirmation comes from similar findings on a different sample of motor impaired children in a study by Wann *et al*. (1998) using the moving room paradigm of Lee and Aronson (1974). They found that there was a significant group effect such that children with DCD displayed significantly greater standing sway than both the age-matched controls and younger nursery children with their eyes closed. The DCD children were also more sensitive to perturbation by visual motion and they were identified by the Movement ABC test as having problems in balance when they were compared with the control group.

Given that visual information relays to both hemispheres, interhemispheric co-operation is important in co-ordinating visual information from the right and left visual fields (Estil *et al*. 2003). Problems in co-ordinating this information may be a contributory factor to difficulties in maintaining balance. Thus, a problem in callosal transfer of information might also affect postural skills. Of interest here is the role of cerebellum, and that lesion to different areas of the cerebellum may result in clumsy, uncoordinated movements but this does not necessary mean poor postural control.

The aim of the present study is to examine static balance on one leg in children with and without HECP. Such children were compared on three different balance tasks with the right and/or left leg together with a systematic manipulation of vision.

The question is whether the children with HECP have more problems, in general, with balance when the scores for both legs are combined? Do these children also experience more problems with their left (non-preferred) leg when separate analyses for each leg are carried out?

Materials and methods

Participants

All methods and procedures were administered in accordance with the Declaration of Helsinki. To ensure that the group of children participating in this study was as homogeneous as possible, a one-step selection procedure was adopted. Eighty-eight school children aged 9–10 years (the total population of a local school) were evaluated on tasks demanding hand–eye co-ordination. For this purpose, the Movement ABC test (Henderson & Sugden 1992) was used, the children being ranked on the basis of their summed scores on the five hand–eye co-ordination subtests: throwing a bean bag, following a flower trail, playing bounce and catch, placing pegs and threading a lace. The 12 children with the highest scores (a high score indicating HECP) were designated the HECP group, while the 12 children with the lowest scores constituted the control group (Table 1).

Table 1. Gender (M/F), chronological age (CA), Movement Assessment Battery for Children scores (manual dexterity and ball skills) and total score for the group with hand–eye co-ordination problems (HECP) ($n = 12$) and the control group ($n = 12$)

HECP group					**Control group**				
Subject	**CA (years)**	**Manual dexterity**	**Ball skills**	**Total score**	**Subject**	**CA (years)**	**Manual dexterity**	**Ball skills**	**Total score**
1 (M)	10.4	8.0	10.0	18.0	13 (M)	10.3	1.0	0	1.0
2 (F)	10.7	7.0	9.0	16.0	14 (M)	10.3	1.5	0	1.5
3 (F)	10.4	6.5	9.0	15.5	15 (F)	10.9	1.5	0	1.5
4 (M)	10.6	10.0	4.0	14.0	16 (F)	10.3	1.5	0	1.5
5 (F)	10.4	5.0	9.0	14.0	17 (F)	10.4	1.0	1.0	2.0
6 (F)	10.6	7.0	6.0	13.0	18 (F)	11.1	2.0	0	2.0
7 (F)	10.4	6.0	7.0	13.0	19 (F)	10.9	2.0	0	2.0
8 (M)	10.3	3.0	10.0	13.0	20 (M)	10.3	2.0	0	2.0
9 (F)	11.0	6.0	7.0	13.0	21 (F)	11.1	2.5	0	2.5
10 (F)	11.1	8.5	4.0	12.5	22 (M)	10.6	2.5	0	2.5
11 (F)	10.4	3.0	8.0	11.0	23 (M)	11.0	1.0	2.0	3.0
12 (F)	10.9	3.0	7.0	10.0	24 (F)	11.2	2.0	1.0	3.0
Mean	10.6	6.1	7.5	13.6		10.7	1.7	0.3	2.0
SD	0.27	2.27	2.08	2.16		0.37	0.54	0.65	0.62

The mean chronological age for the HECP group was 10.6 years (SD 0.27) and for the control group 10.7 (SD 0.37), the overall range being 10.3–11.2. The group with motor problems consisted of three boys and nine girls, whereas in the control group there were five boys and seven girls. The Edinburgh Handedness Inventory (Oldfield 1971) was used to test these children on hand preference and the results showed that all children were right-handed. Bruininks' (1978) test involving kicking a tennis ball three times was used to measure foot preference, and all children participating in this study ($n = 24$) was right-footed.

Movement ABC test

The Movement ABC test is a formal, standardized test designed to identify children with motor co-ordination problems. The test was developed by Henderson and Sugden (1992), and is an extended version of the well-known Test of Motor Impairment (Stott *et al.* 1984). It provides both a quantitative and a qualitative evaluation of the child's motor competence in daily life. The test battery contains eight subtests, which are divided into three categories: three tests of static and dynamic balance, three test of manual dexterity and two tests of ball skills. The test battery employs different tasks for children of different ages. For each age band, a given child's performance is referenced to a standardization sample of children of the same age. On the basis of these norms, it is possible to establish whether a child has a normal motor performance (compared with 85% of children of the same age), borderline performance (85–95%) or belongs to the 5% with a deviant performance (95–100%). In this age group, an ABC score of 10 would place the child at the 15th percentile and a score greater than 13.5 at the 5th percentile. An idea of how impaired these children were can be seen as all children in the HECP sample had scores of 10.0 or over. As the sole concern of this study was with children showing deficits in hand–eye co-ordination, only five of the eight subtests were used. On the basis of the norms for these subtests alone, a score of 7.5 would place the child at the 15th percentile and a score greater than 11.5 at the 5th percentile.

Apparatus

For the first condition, when the subject was standing on the floor, no specific apparatus were used. This task is the same as that used in Movement

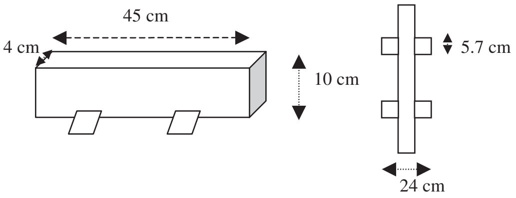

Figure 1. Exact measures of the beam used in the balance on beam task, seen from the side and above.

ABC test (Henderson & Sugden 1992) for age band 2 (7–8 years).

For the second condition, a balance beam, first tried out in the pilot study, was used (Fig. 1).

For the third condition, the child stood on a balance board, the same as that used in Movement ABC test (Henderson & Sugden 1992) for age band 3 (9–10 years).

An ordinary child-sized Scott ski mask covered with aluminium foil was used to blindfold the children.

Procedure

Subjects were tested at their school in a quiet room where they were alone with the experimenter. All were told to bring their shoes for the experiment. Before the experiment started, a brief explanation of the different tasks and the purpose with it was told to the subject.

Prior to the experiment, the dominant hand and foot were recorded for each subject. To test the subject hand preference, the Edinburgh Handedness Inventory was administered. However, instead of questioning the children (the normal procedure), they were actually observed while carrying out each of the activities.

The second step was to test foot preference. The dominant foot was determined by observing the children kicking a tennis ball. The leg they choose to kick with was known as the preferred leg, and the leg they choose to stand on was the non-preferred leg.

The third step was to give one practice attempt of up to 10 s to see if the child understood the task. So, before the experiment started, the tasks were demonstrated to the child while the main features were explained.

The balance tasks were divided into different series, e.g. stork stand, eyes open, preferred and non-preferred leg. Three trials on each leg was one series. After each such series, the children were allowed to rest for 1 min before the next series began. In the break, they had to walk or do something else, but not practise the experiment.

In the experiment, the child stood facing the experimenter on the floor and on the beam/board, as the different conditions required. The experimenter stood 1.5 m from the child on tape, another tape on the floor indicating the position of the board/beam, and controlled the time and the performance of the balance. The child had clear space, away from walls and furniture.

The experimenter decided the order in which the tasks were performed (see Experimental conditions). The testing was carried out with both the preferred and non-preferred leg, with and without vision.

Experimental conditions

Three different static balance tasks were used:

1. Stork stand: the child stood on one foot and places the sole of the other foot against the side of the supporting knee for up to 60 s. The hands are placed on the hips with the fingers facing forward.
2. Balance on beam: the child balanced on one foot on a beam, hands free to use if necessary, for up to 60 s.
3. One-board balance: the child balanced on one foot, on a board, hands free to use if necessary, for up to 60 s.

There were 12 conditions in total:

1. stork stand, with vision, preferred foot
2. stork stand, with vision, non-preferred foot
3. stork stand, without vision, preferred foot
4. stork stand, without vision, non-preferred foot
5. balance on beam, with vision, preferred foot
6. balance on beam, with vision, non-preferred foot
7. balance on beam, without vision, preferred foot

8 balance on beam, without vision, non-preferred foot
9 one-board balance, with vision, preferred foot
10 one-board balance, with vision, non-preferred foot
11 one-board balance, without vision, preferred foot
12 one-board balance, without vision, non-preferred foot

For each condition, the time (s) was recorded using a stop watch. Timing started when the subject assumed the proper position and indicated that he/she was ready. The time was stopped when the following conditions occurred: movement of either foot from the proper position, displacement of the weight-bearing foot, suspended foot touching the ground, or use of the suspended limb to support the weight-bearing limb.

Results

The mean scores (measured in seconds) of three different static balance tasks for the two groups, designated as HECP and control, are illustrated in Tables 2 and 3. Table 2 presents general differences between the two groups with the scores for both legs combined, while Table 3 shows the scores for each leg separately.

Differences between the HECP group and the control group

Significant differences (Mann–Whitney *U*-test,[3] one-tailed) between the two groups were noted in all three tasks, with and without vision, favouring the control group (see Table 2): stork stand with vision ($P = 0.02$), without vision ($P = 0.004$); balance on beam with vision ($P = 0.003$), without

		HECP group		**Control group**		
		Mean	**SD**	**Mean**	**SD**	***P****
Stork stand	V	32.19	21.15	49.55	15.72	0.02
	NV	9.21	8.32	21.47	14.88	0.004
Balance on beam	V	10.85	12.12	23.97	15.54	0.003
	NV	2.81	0.94	3.75	1.29	0.03
One-board balance	V	4.87	4.76	12.67	11.65	0.001
	NV	2.17	0.72	3.01	1.12	0.04

V, vision; NV, non-vision.
*Mann–Whitney *U*-test (one-tailed).

Table 2. Means and SD of the score (measured in seconds) for each of the three conditions of the experiment for the group with hand–eye co-ordination problems (HECP) and the control group, together with the *P*-values for the differences between groups with the scores for both legs combined

			HECP group		**Control group**		
			Mean	**SD**	**Mean**	**SD**	***P****
Stork stand	V	P	35.69	24.80	48.18	16.87	NS
		NP	28.69	20.85	50.91	17.45	0.01
	NV	P	9.49	10.25	23.17	20.91	0.03
		NP	8.93	7.75	19.76	19.70	0.03
Balance on beam	V	P	10.54	12.38	17.14	11.88	0.04
		NP	11.17	12.13	30.81	23.60	0.006
	NV	P	3.03	1.35	3.53	1.51	NS
		NP	2.58	0.91	3.97	2.34	NS
One-board balance	V	P	5.46	6.31	15.97	20.98	0.009
		NP	4.29	3.75	9.38	6.31	0.001
	NV	P	1.99	0.72	3.43	1.50	0.003
		NP	2.36	0.99	2.58	1.12	NS

V, vision; NV, non-vision; P, preferred leg (right leg); NP, non-preferred leg (left leg).
*Mann–Whitney *U*-test (one-tailed).

Table 3. Means and SD of the scores (measured in seconds) for each of the three conditions in the experiment for the group with hand–eye co-ordination problems (HECP) and the control group, together with the *P*-values for the differences between groups for each leg separately

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[3] Given that the sample was not randomly chosen and the data were not normally distributed, the non-parametric statistic was used.

vision ($P = 0.03$); one-board balance with vision ($P = 0.001$), without vision ($P = 0.04$).

However, as Table 2 shows, vision plays an important role for both groups. In the control group, outcomes within the same task were: stork stand, 28.08 s ($P = 0.002$); balance on beam, 20.22 s ($P = 0.002$); and one-board balance, 9.66 s ($P = 0.002$). The results for the HECP group were as follows: stork stand, 22.98 s ($P = 0.002$); balance on beam, 8.04 s (not significant); and one-board balance, 2.70 s ($P = 0.002$).

Given the possibility of a laterality effect, separate analyses for each leg were carried out.

Differences between each leg separately between the groups

There were differences in scores across all conditions in favour of the control group (see Table 3). The preferred leg, with vision, showed that stork stand had a difference of 12.49 s; balance on beam 6.60 s; and one-board balance 10.51 s. The results for the non-preferred leg also showed a marked mean difference between the two groups: stork stand, 22.22 s; balance on beam, 19.64 s; and one-board balance, 5.09 s. However, the Mann–Whitney *U*-test showed significant differences for the tasks stork stand, non-preferred leg: ($P = 0.01$); balance on beam, preferred leg: ($P = 0.04$); non-preferred leg: ($P = 0.006$); and one-board balance, preferred leg: ($P = 0.009$) and non-preferred leg: ($P = 0.001$). No significant differences between the groups were found for the stork stand, preferred leg.

Furthermore, being required to perform without vision results in a marked decrease in measured time for both groups. The most striking results were in the conditions balance on beam and one-board balance. In these two tasks, the control group scored almost as poorly as the HECP group, with a difference of only 0.50 s for balance on beam on the preferred leg, while the non-preferred leg showed a difference of 1.39 s. In the one-board balance, the difference was 1.44 s on the preferred leg, and 0.22 s on the non-preferred leg. Significant differences (Mann–Whitney *U*-test) were found in the tasks stork stand, preferred leg ($P = 0.03$) and non-preferred leg ($P = 0.03$), and one-board balance, preferred leg ($P = 0.003$). No significant differences were found in balance on beam, preferred leg and non-preferred leg, and one-board balance, non-preferred leg.

Differences between leg performance within groups

Differences between preferred and non-preferred leg within the HECP group showed that in the stork stand task, there is a substantial difference (7 s) when vision is available in favour of preferred leg. In the other two tasks, the difference was not so marked. For balance on beam, the non-preferred leg scored 0.63 s better than the preferred leg; for one-board balance, the preferred leg scored 1.17 s better than the non-preferred leg. However, no significant differences within HECP group were revealed by separate analyses of performance of the right and left leg (Mann–Whitney *U*-test).

In the control group, when vision is available, the differences between preferred and non-preferred leg were: stork stand, 2.73 s in favour of the non-preferred leg; balance on beam, 13.67 s, in favour of the non-preferred leg; and for one-board balance, 6.59 s in favour of the preferred leg. The Mann–Whitney *U*-test showed significant differences between the preferred and non-preferred leg on the balance on beam ($P = 0.05$). However, for rest of the conditions in the control group, there was no significant difference.

When vision was occluded, both groups' scores worsened compared with conditions when vision was available in all tasks. The HECP group displayed a difference of 0.56 s for stork stand; 0.45 s for balance on beam; favouring the preferred leg; and for one-board balance a difference in favour of the non-preferred leg 0.37 s was recorded.

In the control group, the differences between preferred and non-preferred leg when vision was occluded were: stork stand, 3.41 s, favouring the preferred leg; balance on beam, 0.44 s, favouring the non-preferred leg; one-board balance, 0.85 s, favouring the preferred leg. However, no significant differences were found in the conditions when vision was occluded, but the condition one-board balance almost displayed a significant difference between right and left leg for the control group ($P = 0.06$; Mann–Whitney *U*-test).

Discussion

In an attempt to come closer to an understanding of DCD in children, the aim of this experiment was to explore static balance in a group of children with HECP. The point of departure for this study was the studies of Sigmundsson and colleagues of a subgroup of DCD children with HECP using an inter- and intra-modal matching paradigm. In theses studies, they showed that the right-handed HECP group displayed lowered performance when the non-preferred (left) hand was used for locating a target. Estil *et al.* (2003) studied language and motor impairments with the results showing that the group of language impaired children and those with both language and motor impairment had more problems with balancing on the left than on the right leg.

The question is whether the children, referred as having HECP, experience more problems, in general, with balance when the scores for both legs are combined? Do these children also experience more problems with their left (non-preferred) leg when separate analyses for each leg are carried out?

Static balance when the performance of both legs are combined

We succeeded in demonstrating significant differences between the HECP group and the control group, when scores for both legs were combined for all three static balance tasks, thereby replicating the findings of previous studies (Gubbay *et al.* 1965; Illingworth 1968; Reuben & Bakwin 1968; Dare & Gordon 1970; Gubbay 1978; Lesny 1980; Shaw *et al.* 1982; Hulme & Lord 1986).

When vision was occluded, both groups performed less well on all three static balance tasks (Table 2). The role of vision seems to be more important for the control group because they demonstrated substantial differences between tasks with vision compared with those tasks without vision. However, in the two tasks, balance on beam and one-board balance, the control group performed nearly as poorly as the HECP group when vision was occluded. One possible explanation for this pattern might be that the children found it hard to balance without vision when the tasks are more complicated and unfamiliar, such as standing on a beam or a tilt board, and that the role of vision plays an important role for the HECP group as well as the control group.

Comparing the performance of the preferred and non-preferred leg

The HECP group displayed inferior performance on both the preferred and non-preferred leg in all conditions compared with the control group (Table 3).

The most interesting effects revealed were from the task stork stand with vision. The difference between the groups showed that when the preferred leg was used, there were no significant differences. When the non-preferred leg was used, the control group showed significantly better performance compared with the HECP group. This supports the findings in Sigmundsson *et al.* (1997a,b, 1999a) and Sigmundsson (1999), where the focus was on an inter- and intra-matching paradigm. They showed that the difference between the right-handed HECP group and the control group could, on the whole, be attributed to reduced performances with the non-preferred hand, which, in turn, might be accounted for by right hemisphere insufficiency (Heilman & Rothi 1993). The findings from the task stork stand with vision are also in line with Estil *et al.* (2003) study, where they found that the total group of language impaired children and the four subjects with both language and motor impairment had more problems with balancing with vision on the left than on the right leg.

When the tasks get more complicated, such as balance on beam and one-board balance, both the HECP and control group displayed inferior performance compared with stork stand. However, performance on these two tasks with vision showed the HECP group to be significantly worse than controls when using the preferred or non-preferred leg. This might indicate insufficiency within both hemispheres, not only the right hemisphere. This is in line with Sigmundsson *et al.* (1999b) study, where it was found that performance on a task 'target location and matching' showed that the motor-impaired children performed significantly less well than controls with both hands. It was proposed that insufficiency within both hemispheres, with or without a dysfunctional corpus callosum, could be one possible factor contributing to the problems that motor-impaired children are reported to encounter in more complex tasks, such as dressing, doing up buttons and shoelaces, ball games, etc. and for almost every task when temporal constraints are imposed (for a review see Smyth 1992).

Under the non-vision condition, both HECP and control groups displayed inferior performance in all conditions. For stork stand, the HECP group showed significant differences on both preferred and non-preferred leg compared with the control group. This supports Wann *et al.* (1998) findings that there was a significant group effect, with DCD children displaying significantly greater standing sway than both the age-matched controls or younger nursery children with their eyes closed. The DCD children also showed more sensitivity to perturbation by visual motion and they were identified by the Movement ABC test as having problems with balance when compared with the control group.

However, the HECP and control group, for the two tasks balance on beam and one-board balance, without vision, showed almost same score on both legs. This might be explained by the idea that when the tasks get more difficult, the role of vision becomes more important. Therefore, when the task is performed without vision, there is a decrease in performance.

Differences between leg performances within groups

In the control group, the differences between preferred and non-preferred legs showed that when vision was available, the non-preferred leg was scored favourably in relation to the preferred leg in two of three tasks (Table 3). However, the only task that showed a significant difference was balance on beam, favouring the non-preferred leg. The difference between the performances of the two legs separately within the HECP group showed that the preferred leg performed better in only one condition, stork stand with vision, but it was not significant. In both the balance on beam and one-board balance tasks, the difference between preferred and non-preferred leg was not so distinct.

Performing the tasks without vision, both the HECP and control group showed almost the same mean score between their preferred and non-preferred leg. It seems to be the case that when vision is not available, the distinction between the two legs is smaller for both groups.

But what is the preferred leg and is it developmentally normal that there should not be any difference in performance when balancing on the right or the left leg? The question about the preferred and non-preferred leg in static balance does not seem to be as clear-cut as that for the preferred versus non-preferred hand, for either of the groups. Peters (1988) pointed out that the assessment of footedness in humans is complicated by the interactions between hands and feet, and by the fact that the activities of the feet are relative to those of the hands, less complex and less often overlearned. As a result, the lateral bias towards one or the other side may not be as compelling as for hands. The lack of hand–foot congruence should therefore be seen relative to the fact that foot preference has a weaker status than hand preference (Peters 1988).

Regarding the normal development and the performance in balance tasks on the right or the left leg, there is no doubt as to the importance of sensory integration in balance. Bogen (1990, 1993) and Waal *et al.* (2000) pointed out, in this respect, a potential independence of the hemispheres, and when it comes to somaesthetic information, whether haptic or proprioceptive, there is little evidence of hemispheric dominance. This might lead to the conclusion that the control group displays a well-developed spatial system in each hemisphere, and therefore the difference between preferred and non-preferred leg is not so distinct. The HECP group also displays no difference between the performances of the right or the left leg. However, their performance is, in general, less well than the control group. This suggests some kind of lack of development within both hemispheres. But, as Glickstein (1990) pointed out, it must be recognized that the HECP group performance could be related to a lack of development in the basal ganglia, reticular formation and the cerebellum – all important structures in motor co-ordination.

Conclusion

The intention of the present study was to explore whether children with HECP, compared with the control group, have, in general, more problems in static balance. A further aim was to see if this group experiences more problems when standing on their non-preferred leg (left) than their preferred leg (right). The findings supported the hypothesis that children with HECP, in general, do have more problems with static balance. The study partly succeeded in showing that the HECP group performed less well with the non-preferred leg, compared with their preferred leg. However, this study points to insufficiency within both hemispheres, and not only the right hemisphere.

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