Changes in Gait Balance and Brain Connectivity in Response to Equine-Assisted Activity and Training in Children with Attention Deficit Hyperactivity Disorder

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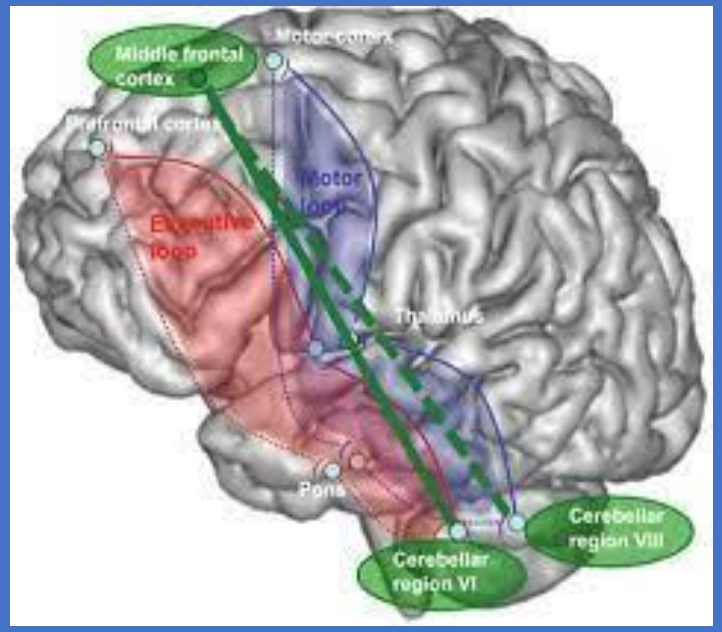
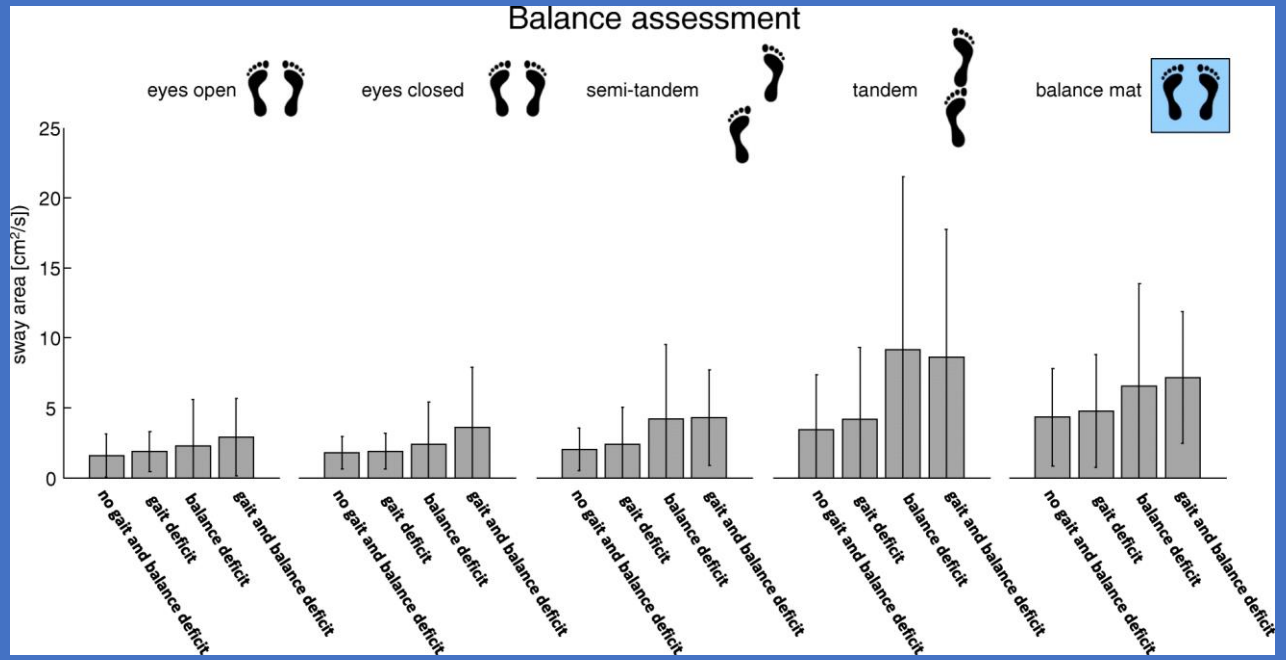
Attention Deficit Hyperactivity Disorder

Clinical symptoms	Cognitive functions	Brain Activity
• inattention • Hyperactivity • impulsivity	• Working memory deficit • Motor dysfunction	• Fronto-parieto cerebellar network • Cerebellar dysfunction


Middle frontal cortex
Motor cortex
Prefrontal cortex
Motor loop
Executive loop
Thalamus
Pons
Cerebellar region VIII
Cerebellar region VI


Balance assessment
eyes open
eyes closed
semi-tandem
tandem
balance mat
sway area (cm²/s))
25
20
15
10
5
0
no gait and balance deficit
gait deficit
balance deficit
gait and balance deficit

Equine-assisted activity and therapy (EAAT)

S1: learning horse walking,

S2: riding posture at walk and sitting trot,

S3: rhythm of sitting trot,

S4: changing direction (including half-volte to wall)/making small (10-m) circles,

S5: half-seated posture with hands,

S6: half seated posture without hands,

S7: diagonal posting trot in the ring arena,

S8: posting and sitting trot in the ring arena,

S9: diagonal posting trot in the ring arena,

S10: making circles with posting and sitting trot in the small arena,

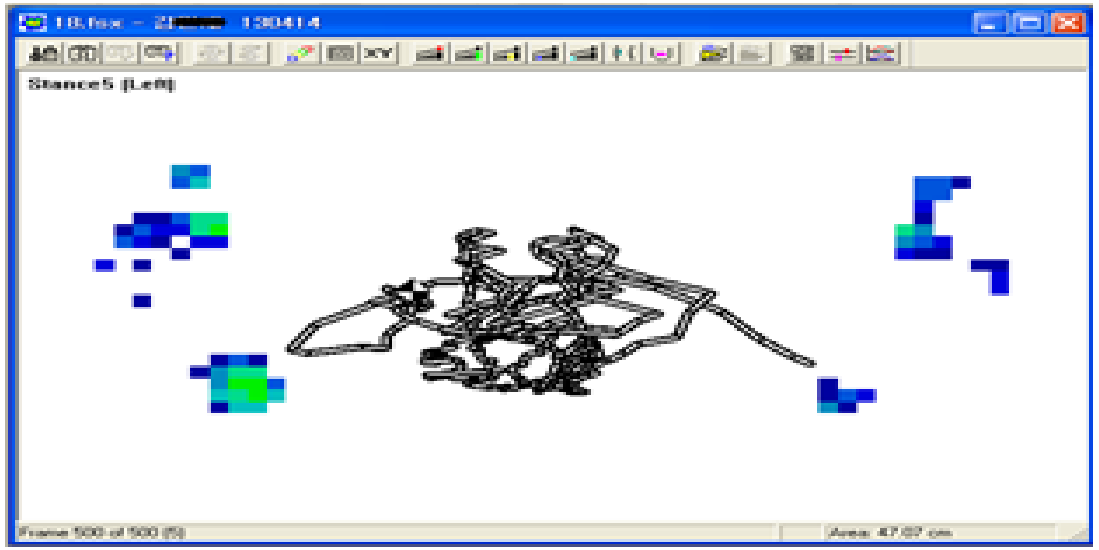
S11: staying straight and changing direction by crossing the long diagonal in the small arena

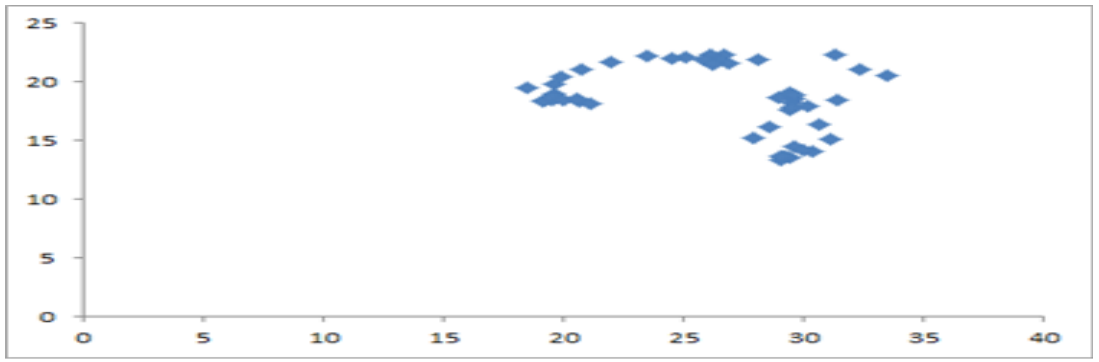
S12: figure-eight with posting trot in the small arena

Brain Scan and analysis

- Brain scans were obtained from all children by using a 3.0-
- Tesla Verio MRI scanner (Siemens, Erlangen, Germany).
- a gradient-echo planar sequence sensitive to blood oxygen level–dependent contrast (repetition time], 3000 milliseconds; echo time, 30 millisecond; flip angle, 90)
- Brain Voyager software

Gait balance





- The difference in the COP between left and right foot
- The peak pressure within seven regions of the foot: lateral heel, medial heel, midfoot, first metatarsaophalangeal joint, second to fifth metatarsaophalangeal joint, hallux, lesser toes

Changes in clinical symptoms

TABLE 1. DEMOGRAPHIC AND CLINICAL CHARACTERISTICS

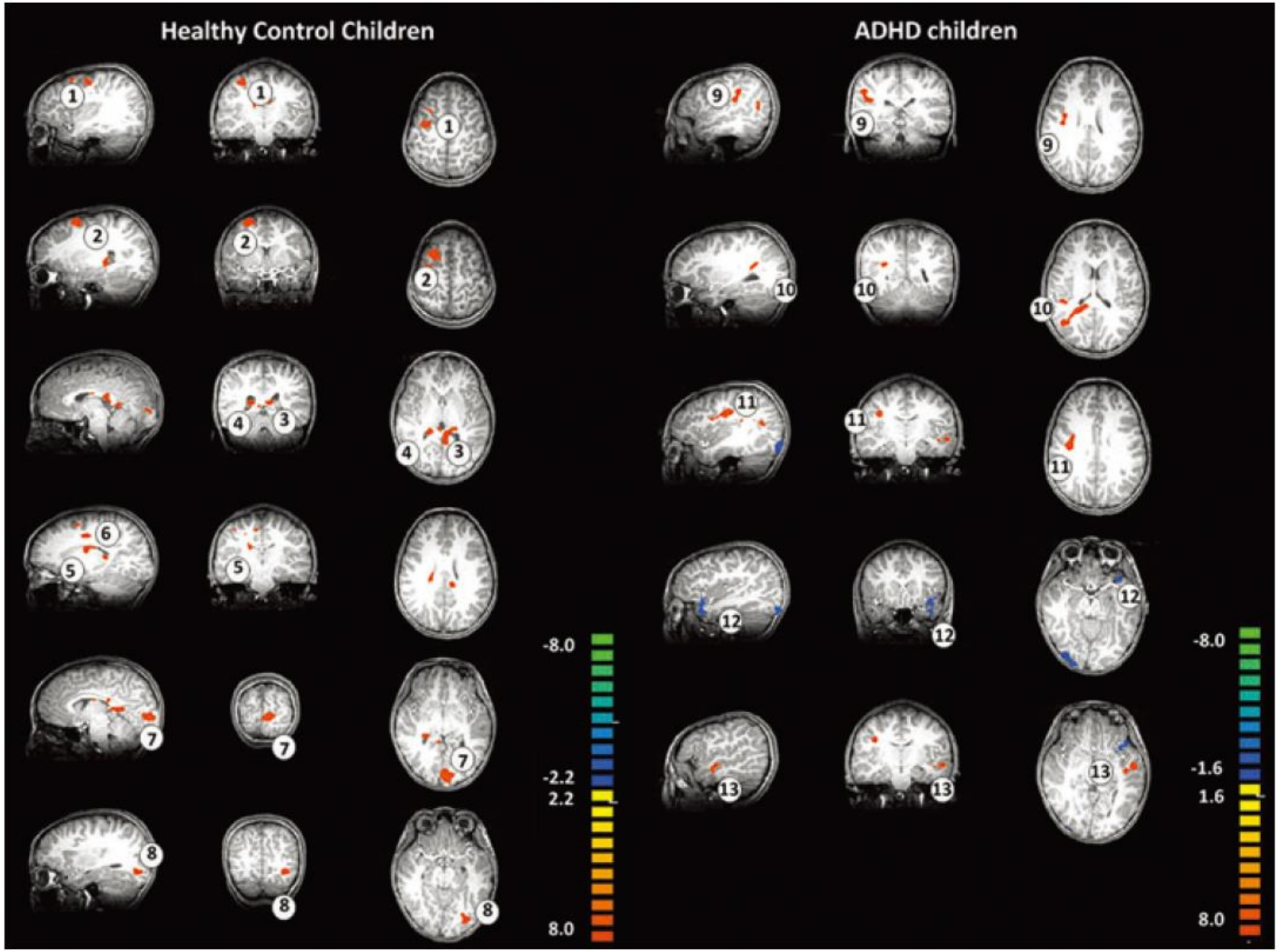
Characteristic	*ADHD group (n = 12)*	*Control group (n = 12)*	*Statistical analysis*
Age (yr)	10.8 ± 1.4	10.3 ± 1.2	$z = 0.87$, $p = 0.39$
Boys/girls (*n*/*n*)	9/3	8/4	$\chi^2 = 0.2$; $p = 0.65$
Education (yr)	4.7 ± 1.2	4.3 ± 1.1	$z = 0.90$; $p = 0.37$
IQ	96.8 ± 9.7	97.0 ± 8.2	$z = 0.43$; $p = 0.66$
K-ARS score			
Baseline	26.0 ± 6.4	4.3 ± 3.0	$z = 4.12$; $p < 0.01$[a]
4 wk	19.6 ± 3.1	3.1 ± 2.4	$z = 4.16$; $p < 0.01$[a]
	$z = 3.18$; $p < 0.01$[a]	$z = 0.95$; $p = 0.34$	RANOVA, $F = 16.1$; MS = 80.0; $p < 0.01$
CDI score	±	±	
Baseline	8.6 ± 5.4	7.7 ± 6.0	$z = 0.29$; $p = 0.77$
4 wk	6.6 ± 4.1	4.8 ± 4.1	$z = 1.10$; $p = 0.27$
	$z = 2.84$; $p < 0.01$[a]	$z = 3.02$; $p < 0.01$[a]	RANOVA, $F = 1.10$; MS = 2.08; $p = 0.31$

Changes in balance

TABLE 2. CHANGES IN PLANTAR PRESSURE DIFFERENCES AND FOOT JERK VALUES

Variable	*ADHD* (n = *12*)	*Control* (n = *12*)	*Statistical analysis*
Plantar pressure			
Left foot			
Baseline	48.5 ± 1.3	49.4 ± 1.1	$z = 2.22$; $p = 0.03$[a]
4 wk	49.6 ± 1.2	49.5 ± 0.9	$z = 0.26$; $p = 0.79$
Right foot			
Baseline	51.5 ± 1.3	50.6 ± 1.1	$z = 2.22$; $p = 0.03$[a]
4 wk	50.5 ± 1.3	50.1 ± 0.8	$z = 0.95$; $p = 0.34$
Difference			
Baseline	3.7 ± 1.4	1.91 ± 1.5	$z = 2.71$; $p < 0.01$[a]
4 wk	2.1 ± 1.5	1.0 ± 0.9	$z = 1.61$; $p = 0.11$
	$z = 2.28$; $p = 0.02$[a]	$z = 2.24$; $p = 0.03$[a]	RANOVA, $F = 1.23$; MS = 1.76; $p = 0.28$
COP jerk value			
Left foot			
Baseline	1.5 ± 0.3	1.3 ± 0.2	$z = 1.18$; $p = 0.23$
4 wk	1.2 ± 0.3	1.2 ± 0.2	$z = 0.66$; $p = 0.51$
	$z = 2.6$; $p = 0.01$[a]	$z = 1.41$; $p = 0.16$	RANOVA; $F = 3.53$; MS = 0.11; $p = 0.06$
Right foot			
Baseline	1.5 ± 0.3	1.3 ± 0.2	$z = 2.02$; $p = 0.04$[a]
4 wk	1.3 ± 0.2	1.2 ± 0.2	$z = 0.29$; $p = 0.77$
	$z = 2.5$; $p = 0.01$[a]	$z = 9.8$; $p = 0.33$	RANOVA; $F = 3.67$; MS = 0.12; $p = 0.06$

Changes in brain connectivity



Discussions

- Several reports have indicated that horse riding improves clinical symptoms in children with ADHD
- In EAAT, the rhythmic and repetitive movement of the horse is thought to stimulate motor neurons and enhance input information to the motor system, similar to the movement patterns of the pelvis when walking
- We suggest that EAAT improves connectivity within the fronto-striato-cerebellum in ADHD children, like other treatments including medication, neurofeedback, and aerobic exercise.

Conclusion

- EAAT may improve clinical symptoms, gait balance, and brain connectivity, the last of which controls gait balance, in children with ADHD.
- However, children with ADHD who have deficits in the fronto-cerebellar tract did not exhibit changes in brain connectivity as extensive as those in healthy children in response to EAAT.