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Research article

Feasibility study of inertial sensors technology on the pelvic and trunk kinematics during horseback riding in children

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Abstract

Inertial sensors technology (IMU) has been utilized to determine kinematic data for some outdoor activities. Horseback riding (HR) is an alternative treatment that has been reported to be beneficial for children with cerebral palsy (CP). However, understanding the mechanism of improving postural control is unknown. The aim of this study was to investigate the feasible of IMUs to determine pelvic and trunk kinematics during HR in children with CP and with typical development (TD). Twenty children (10 CP, 10 TD; age: 4-12 years) were recruited into the study. The movement of the pelvis and trunk in children with CP and TD including angular displacement and velocity were measured by inertial measurement sensors during horseback riding. Results demonstrated no differences for pelvis and trunk angular displacement or velocity. For children with CP, pelvis and trunk correlations were moderate to good in angular displacement in the sagittal plane ($\rho=0.65$, $p=0.04$ for pelvis and trunk flexion-extension and $\rho=0.75$, $p=0.01$ for pelvis flexion-extension and trunk inclination) and in angular velocity in the frontal and horizontal planes ($\rho=0.82$, $p=0.02$ for lateral flexion and $\rho=0.73$, $p=0.02$ for rotation). For children with TD, pelvis and trunk correlations were moderate to good only for angular velocity in the sagittal plane ($\rho=67$, $p=0.03$). In conclusion, it is possible to use IMU technology to capture movement of children during HR. The motion parameters including pelvis and trunk angular displacement and velocity can be used to possibly detect functional impairments and monitor the progress of treatment.

Keywords: Cerebral palsy, Horseback riding, Inertial measurement units, Postural control

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INTRODUCTION

Horseback riding (HR) facilitates increased postural reaction by improving sensory processing that is important in modifying motor responses (MacPhail et al., 1998). Horse movement during riding is a continuous passive displacement of the rider's center of gravity (COG) that enables automatic postural equilibrium reaction of the head and trunk (Temcharoensuk et al., 2015). In addition, smooth and rhythmic pelvic movement of the horse is similar to human gait (Garner and Rigby, 2015). Therefore, human postural reaction in response to horse movement for maintaining a stable position in a dynamic environment is considered as a dynamic postural control in human movement. Functional level assessment tests are often used to measure the effects of HR on sitting postural control in children with cerebral palsy (CP) (Stergiou et al., 2017; Wood and Fields, 2019), including gross motor function measurement (GMFM), segmental assessment of trunk control (SATCo) (Temcharoensuk et al., 2015) and the Sitting Assessment Scale (SAS) (Matusiak-Wieczorek et al., 2020). These functional tests are easy to use but provide a rough and indirect measurement tool for postural reaction assessment. Effects of HR are routinely measured after dismounting the horse, which is not representative of real postural reaction. Therefore, current investigation of the mechanism of real-time effects of HR in children with CP is insufficient. To our knowledge, only one prior study investigated the immediate effect of therapeutic HR in children with CP and with typical development (TD), by conducting a kinematic analysis of riders' lateral trunk movement relative to horse pelvic movement (MacPhail et al., 1998). The results showed that the mean maximum lateral trunk displacement of children with CP (10.2 degrees; ranged from 6.9-13 degrees) was almost twice as great as children with TD (5.8 degrees; ranged from 5.2-6.6 degrees). Nevertheless, a limitation of this study was that trunk movement was measured only in the frontal plane. Tools which can directly measure human motion along all three planes while horseback riding are needed.

Inertial sensors technology (IMU) has been developed to measure kinematic data for several outdoor activities including gait analysis in the community (Cuesta-Vargas et al., 2010). IMU can track motions in three dimensions, are lightweight, easy to use, portable, and enable data acquisition during natural conditions such as during HR. Therefore, the aim of this study was to determine the feasibility of an IMU to evaluate kinematic data of the pelvic and trunk in all planes during HR among both children with CP and with TD. Results of this study may help clinicians detect impairment and provide guidance to develop treatment programs involving HR activity and therapy.

MATERIALS and METHODS

Participants

The sample size for a 2-group comparison on kinematic analysis was calculated based on the results of lateral trunk displacement from MacPhail et al. (1998) using G*power 3.1.9.2. With a power of 0.80, a 0.05 alpha level, two-tailed, and large effect size in t-test family, the estimated sample size was a total of 8 participants (4 children with CP and 4 children with TD). However, the estimated sample size for correlation was a total of 9 participants (using two-tailed bivariate correlation in G*power with a correlation ρ H1 of 0.80, a 0.05 alpha level, and 0.80 power). Therefore, ten children with diplegic CP and ten children with TD were recruited into the study. Participants were included in the study if they were aged between 4 and 12 years with a bodyweight no more than 10 % of the bodyweight of the horse, and had no experience in horseback riding (experience was defined as horseback riding therapy at least 1-2 times/week for more than 6 months). Children with diplegic CP were classified according to the Gross Motor Function Classification system (GMFCS) within level III, and able to follow instructions. The exclusion criteria consisted of surgical or Botox interventions within the past 6 months and uncontrolled seizure. All participants were recruited through public advertisements and contact with local physical therapists. A full explanation of the procedures was provided, and informed consent was obtained from the parents or caregivers, prior to enrollment into the study. This study was approved by the ethics committee of Chiang Mai University (Ethic Code: AMSEC-61EX-031). All 20 children rode on the same pony, at the horse's self-selected comfortable walking speed.

Procedure

Following informed consent, participants completed a personal data collection form providing information on age, gender, anthropometric data including weight and height, diagnosis, and experience in horseback riding. A pony was chosen because its walking speed is closed to human walking speed (Clayton, 2002). The pony was a well-trained, 11.5-hand-height mare which has served equine-assisted therapy and activities for more than 5 years.

Eight inertial sensors were placed by one assessor (TT) on the body following a software program template (Figure 1), including left (Lt) and right (Rt) foot, left (Lt) and right (Rt) shanks, left (Lt) and right (Rt) thighs, sacrum (S2) and trunk (T4). A portable personal computer with the inertial software (STT system, Spain) was connected to the sensors via WIFI (2.4 GHz – 5 GHz). Each sensor included a 3-axis gyroscope, 3-axis accelerometer, and 3-axis magnetometer. The sensor size was 56 x 38 x 18 mm., weight 46 g., with a sampling rate of 400 Hz. The position of each sensor placed on a child's body was identified and paired for their reference by the software to obtain the angular displacement and velocities of the rider's pelvis and trunk in three dimensions during HR (Figure 2). The inertial measurement sensors have previously been shown to have excellent validity (Cho et al., 2018; Cuesta-Vargas et al., 2010), with a coefficient of multiple correlation (CMC) ranging between 0.829 - 0.998 when used for motion analysis (Cho et al., 2018). Before data collection, test-retest reliability in this study was conducted, with the intraclass correlation coefficients ranging from 0.919-0.995.

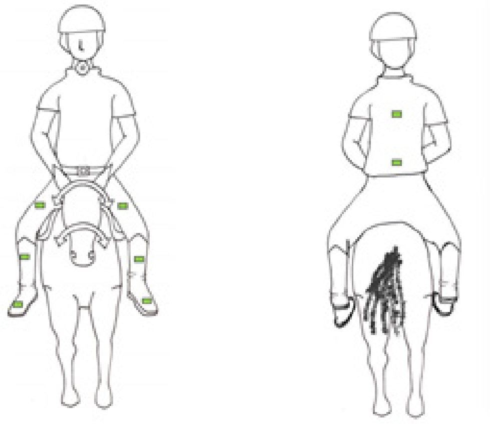

Figure 1 Placement of the inertial motion unit sensors.

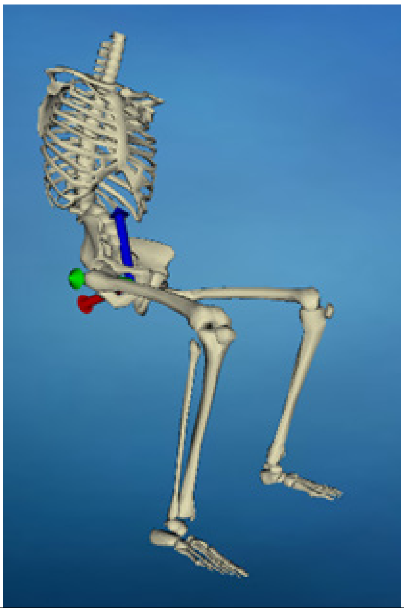

Figure 2 Model of the rider's pelvis and trunk during HR from the inertial motion unit sensors.

Participants wore an appropriate helmet while sitting on the pony and were asked to hold the pommel of the saddle. Three examiners/assistants were required during all HR activity. One handler led the pony at a walk, and two side-walkers walked at the pony's side to ensure safety and that all protocols were performed correctly. The side walkers did not provide any postural support to the child. Before data collection, children were allowed to familiarize themselves with the pony. During data collections, the pony performed straight-line walking for 13 meters across three trials (MacPhail et al., 1998). Data obtained from the middle three strides of the pony for each trial were selected for further analysis. The pony stride started when the pony's left hip reached maximum elevation, based on visual analysis. The end of the pony stride was determined when the left hip returned to a maximum point.

Data acquisition and analysis

The data for analysis were selected from 9 completed strides of the pony for each participant. Pelvic and trunk angular displacement and velocity in each dimension for the rider were averaged and normalized into 100% of the pony's gait cycle (Figure 3). Then the root mean square (RMS) of all variables was computed to represent the discrete variables from the continuous variables (movement in 100% of the horse gait cycle as a function of time). Independent paired t-test and chi-square were used to compare the demographics between groups. The Mann Whitney U test was used to compare differences in pelvis and trunk displacement and velocity across all planes between groups. The Spearman rank-order correlation coefficient (ρ) was used to determine the correlation between pelvis and trunk angular displacement and velocity variables. All statistical analyses were performed using SPSS version17 for Windows (SPSS Inc., Chicago). A p-value of less than 0.05 was considered statistically significant.

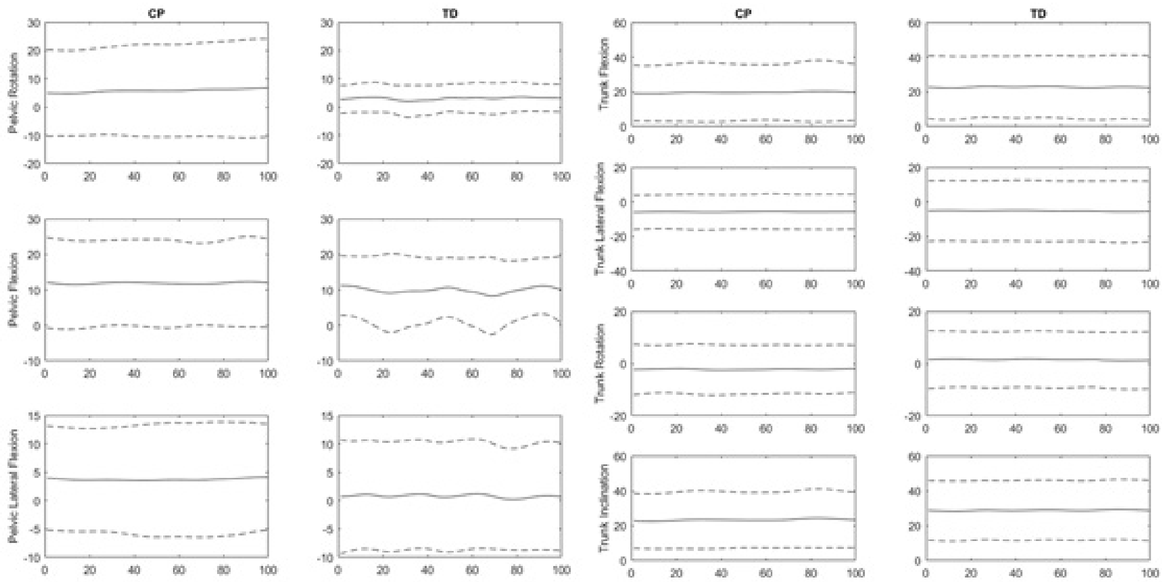

Figure 3 Normalized pelvic and trunk angular displacement of both children with typical development (TD) and with cerebral palsy (CP) across the pony's gait cycle.

RESULTS

Demographics of the participants

There were no differences between children with CP and TD in terms of height, weight, and age (Table 1).

Angular displacement and velocity of pelvis and trunk

No differences were found for pelvis and trunk angular displacement and velocity in all directions (Table 2). For children with TD, the interquartile ranges for pelvic angular displacement ranged between 5.19 and 16.25 degrees, trunk angular displacement ranged between 12.42 and 35.62 degrees, pelvic angular velocity ranged between 4.82 and 19.64 degrees/second, and trunk angular velocity ranged between 7.71 and 32.81 degrees/second (Table 2). For children with CP, the interquartile ranges for pelvic angular displacement ranged between 4.95 and 14.10 degrees, trunk angular displacement ranged between 5.23 and 34.22 degrees, pelvic angular velocity ranged between 5.70 and 10.98 degrees/second, and trunk angular velocity ranged between 8.84 and 13.87 degrees/second. (Table 2). For children with TD, a significant correlation between the pelvis and trunk was only found in the sagittal plane (flexion-extension) velocity (Table 3). For children with CP, significant correlations between the pelvis and trunk were found in the sagittal plane for pelvis and trunk flexion-extension and for pelvis flexion-extension and trunk inclination displacement and in the horizontal and coronal planes velocity (Table 3).

Table 1 Demographic data (mean ± SD) for children with typical development (TD) and cerebral palsy (CP)

Measure	TD (n=10)	CP (n=10)	P-value
Male/Females	4/6	6/4	0.37[a]
Age (years)	7.6 ± 2.1	7.8 ± 1.3	0.68[b]
Weight (kg)	24.3 ± 7.0	25.0 ± 2.0	0.82[b]
Height (cm)	124.5 ± 13.1	126.4 ± 6.0	0.37[b]

[a] the chi-square test was used

[b] the independent paired t-test was used

Table 2 Angular displacement and velocity of pelvis and trunk of children with typical development (TD) and cerebral palsy (CP)

Angular displacement and velocity		TD				CP				
		Mean± SD	Min-Max	Median	Interquartile range	Mean± SD	Min-Max	Median	Interquartile range	**P-value**
Pelvis	**Flexion-Extension (°)**	13.19±8.84	4.15-28.22	11.46	16.25	14.72±8.91	4.43-32.07	15.31	14.10	0.90
	Lateral Flexion (°)	8.64±6.00	2.57-19.15	5.11	9.94	9.61±5.41	4.62-21.38	7.97	7.25	0.37
	Rotation (°)	7.46±4.63	3.62-18.35	6.32	5.19	10.30±4.31	2.18-16.82	11.34	4.95	0.13
	Flexion-Extension Velocity (°/s)	27.99±12.53	4.91-43.19	31.18	19.64	32.77±11.79	3.60-46.71	36.54	10.22	0.63
	Lateral Flexion Velocity (°/s)	22.74±9.22	13.10-39.53	19.87	16.40	22.93±9.19	4.01-36.65	23.3	10.98	0.74
	Rotation Velocity (°/s)	19.30±4.28	9.64-24.52	18.67	4.82	17.06±6.16	2.85-25.15	17.41	5.70	0.22
Trunk	**Flexion-Extension (°)**	23.14±17.70	4.38-49.26	15.20	35.62	20.49±15.82	2.56-39.74	17.65	34.22	0.34
	Inclination (°)	28.97±17.02	4.90-49.30	28.49	30.89	23.46±16.08	4.51-43.07	22.95	33.87	0.26
	Lateral Flexion (°)	12.04±13.43	1.64-45.29	6.68	15.55	9.32±6.85	3.31-25.17	6.87	8.72	0.34
	Rotation (°)	8.06±7.02	0.76-19.13	4.47	12.42	7.85±5.57	3.18-22.11	5.73	5.23	0.43
	Flexion-Extension Velocity (°/s)	24.85±15.34	8.00-46.66	21.81	32.81	23.94±9.98	2.35-38.28	22.81	12.16	0.38
	Inclination Velocity (°/s)	25.10±11.21	10.31-45.63	23.00	18.14	22.87±9.68	2.41-39.20	24.52	8.84	0.34
	Lateral Flexion Velocity (°/s)	14.43±6.67	2.86-27.71	13.87	7.71	20.12±9.34	2.80-38.13	20.34	9.38	0.31
	Rotation Velocity (°/s)	11.15±6.99	5.22-26.07	9.35	9.06	17.12±12.09	2.14-39.23	12.09	13.87	0.40

Table 3 Correlation (ρ) between pelvis and trunk angular displacement and velocity

Pelvis-Trunk correlation	TD		CP	
	ρ	P-value	ρ	P-value
Angular displacement (degrees)				
Flexion-Extension	0.41	0.24	0.65	0.04
Inclination	0.21	0.56	0.75	0.01
Lateral Flexion	0.38	0.28	0.1	0.78
Rotation	0.39	0.26	0.32	0.37
Angular velocity (degrees/second)				
Flexion-Extension	0.67	0.03	0.39	0.26
Inclination	0.60	0.07	0.30	0.41
Lateral Flexion	0.32	0.37	0.82	0.02
Rotation	0.56	0.09	0.73	0.02

DISCUSSION

This study aimed to determine the feasibility of using an IMU to measure the kinematic motion of the pelvis and trunk in children with CP and with TD in three dimensions during HR. The use of inertial sensor has previously been utilized for human motion analysis. This technology may have the potential to analyze kinematics in various environments, particularly in the HR field.

According to the results, children with TD had kinematic responses indistinguishable from children with CP. This result is not in accordance with the findings of MacPhail et al. (1998), possibly because the HR was a novel task for children with TD. All children with TD in the current study had no experience with HR whereas all children with TD in MacPhail et al.'s study had between 2 weeks - 3 years HR experience. From the motor learning perspective, children with TD might use the strategy of freeze degree of freedom (DF) at the beginning of motor learning (Guimarães et al., 2020). Specifically, during HR children with TD reduce their joint range of motion, with strong correlations demonstrated between body segments such that the trunk and pelvis are coupled and reflect a rigid unit. Therefore, children with TD may attempt to maintain their body on the pony during riding by reducing movement at the pelvis and trunk and may need additional time to adjust their body when performing this new task. In contrast, children with CP demonstrate freezing of the DF due to pathologies intrinsic to CP, including spasticity, poor coordination and muscle stiffness (Rosenbloom, 2007). This result was confirmed based on the correlation between the pelvis and trunk angular displacement, especially in the sagittal plane. The correlation between the pelvis and trunk in flexion-extension and inclination might be due to greater anterior pelvic tilt movement, increased trunk flexion, and larger trunk forward inclination. These patterns are typical in children with CP. This result was similar to a previous study that revealed that increasing speed and balance perturbation in the activities of daily living (ADL) among children with CP directly increased pelvis and trunk coupling movement patterns (Barton et al., 2013).

The interquartile ranges of the pelvis and trunk velocity showed that children with TD demonstrated more variability than those in children with CP.

This finding may also support the evidence that children with CP have postural reaction response difficulty. From a dynamical systems perspective, variability allows flexibility to select or change to learn a new movement pattern through adjusting the appropriate parameters (Piek, 2002).

While the IMU has demonstrated excellent validity and reliability for gait (Cho et al., 2018; Cuesta-Vargas et al., 2010), it has not been widely used for clinical movement analysis, particularly during HR. Future studies should investigate the validity and reliability during this task.

In conclusion, there is a potential of using an IMU to detect pelvs and trunk angular displacement and velocity among children during HR. As IMU are portable, relatively inexpensive, easy to use, and practical for use outside the laboratory environment, they can provide clinicians with an objective tool for evaluating disease progression and guide treatment.

CONFLICT of INTEREST

All authors declare no conflict of interest.

AUTHOR CONTRIBUTION

Taweetip Tabsuri conceived and planned the research methodology, collected and interpreted the data, and wrote the manuscript. Nuanlaor Thawinchai supervised, helped in data collection and interpretation, and contributed to writing this manuscript. Siriporn Peansukmanee helped in data collection, provided the pony information, and proofread this manuscript. Vipul Lugade performed the data calculations and acquisition, helped in the data interpretation, and English proofread this manuscript.

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REFERENCES

Barton, G.J., Hawken, M.B., Foster, R.J., Holmes, G., Butler, P.B., 2013. The effects of virtual reality game training on trunk to pelvis coupling in a child with cerebral palsy. J. Neuroeng. Rehabil. 10, 15-15.

Cho, Y.-S., Jang, S.-H., Cho, J.-S., Kim, M.-J., Lee, H.D., Lee, S.Y., Moon, S.-B., 2018. Evaluation of validity and reliability of inertial measurement unit-based gait analysis systems. ARM 42, 872-883.

Clayton, H.M., 2002. Walk This Way, In: USDF Connection. United State Dressage Federation, Lexington, KY, pp. 39-42.

Cuesta-Vargas, A.I., Galán-Mercant, A., Williams, J.M., 2010. The use of inertial sensors system for human motion analysis. PTR : PTR 15, 462-473.

Garner, B.A., Rigby, B.R., 2015. Human pelvis motions when walking and when riding a therapeutic horse. Hum. Mov. Sci. 39, 121-137.

Guimarães, A.N., Ugrinowitsch, H., Dascal, J.B., Porto, A.B., Okazaki, V.H.A., 2020. Freezing degrees of freedom during motor learning: A systematic review. Motor Control, 1-15.

MacPhail, H.E.A., Edwards, J., Golding, J., Miller, K., Mosier, C., Zwiers, T., 1998. Trunk postural reactions in children with and without cerebral palsy during therapeutic horseback riding. Pediatr. Phys. Ther. 10, 143-147.

Matusiak-Wieczorek, E., Dziankowska-Zaborszczyk, E., Synder, M., Borowski, A., 2020. The influence of hippotherapy on the body posture in a sitting position among children with cerebral palsy. Int. J. Environ. Res. Public Health 17.

Piek, J.P., 2002. The role of variability in early motor development. Infant Behavior and Development 25, 452-465.

Rosenbloom, L., 2007. Definition and classification of cerebral palsy. Definition, classification, and the clinician. Dev. Med. Child Neurol. Suppl. 109, 43.

Stergiou, A., Tzoufi, M., Ntzani, E., Varvarousis, D., Beris, A., Ploumis, A., 2017. Therapeutic effects of horseback riding interventions: A systematic review and meta-analysis. Am. J. Phys. Med. Rehabil. 96, 717-725.

Temcharoensuk, P., Lekskulchai, R., Akamanon, C., Ritruechai, P., Sutcharitpongsa, S., 2015. Effect of horseback riding versus a dynamic and static horse riding simulator on sitting ability of children with cerebral palsy: a randomized controlled trial. JPTS 27, 273-277.

Wood, W.H., Fields, B.E., 2019. Hippotherapy: a systematic mapping review of peer-reviewed research, 1980 to 2018. Disabil. Rehabil., 1-25.

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