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Research Article

Feasibility Study of Inertial Sensor Technology on Ponies for Equine-Assisted Therapy (EAT)

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Abstract

Ponies used in equine-assisted therapy (EAT) (hippotherapy) often carry imbalanced riders, which is a cause for concern as regards the health of the ponies. A low degree of lameness or an abnormal gait is not always detectable by a veterinarian, subjectively, but this is enabled by using a motion analysis equipment. The aim of this study was to evaluate the feasibility of inertial sensor technology utilization to analyze ponies' kinematic motion at walking gait. Ten ponies were instrumented with the inertial sensors and made to walk 20 m in two trials (departure and return) for the forelimb data set (n=10), which was then repeated in the second round for the hindlimb (n=3). The ponies were assigned three interventions: walking with no rider, walking with a rider with typical development (normal rider), and walking with a rider with physical disability (disabled rider). The movement speed, stride length, and stride duration were measured by a video camera. The limb range of motion and the angular velocity were detected by inertial sensors. The results showed that there were no significant differences in the kinematic motion of the forelimb at walking gait for all interventions and no significant differences between the left and the right forelimbs except in the case of the anterior phase of the angular velocity of the arm when walking with a disabled rider ($P<0.05$). The hindlimb data set was not statistically compared due to insufficient "n" number. In conclusion, the inertial sensor technology is feasible to use on pony kinematic motion, especially when the sensor is attached to the forelimb. It seems that the ponies could modify the natural kinematic motion when walking with a load on them.

Keywords: *Pony, Walk, Kinematic, Equine-assisted therapy, Hippotherapy, Inertial sensor*

At-Destekli Terapi İçin Ponilerde Atalet Belirleme Teknolojisinin Fizibilite Çalışması

Özet

At-destekli (equine-destekli) terapide (hipoterapi) kullanılan ponilerin sıklıkla denge sorunlu binicileri taşımaları bu ponilerde sağlık sorununa neden olabilmektedir. Düşük dereceli topallık veya anormal yürüyüş daima veteriner hekim tarafından belirlenemeyebilir ve hareket analiz ekipmanı gerektirebilir. Bu çalışmanın amacı atalet belirleme teknolojisinin fizibilitesini ponilerin kinematik hareketlerinde test etmektir. On adet poni atalet sensorları ile donatıldı ve iki hat boyunca (kalkış ve dönüş) 20 m yürütüldü. Ön ayak veri seti (n=10) sonradan ikinci turda arka ayak (n=3) için tekrar edildi. Poniler 3 uygulamaya maruz bırakıldı: binicisiz yürüme, tipik gelişimli binicili yürüme (normal binici) ve fiziksel engelli binicili yürüme (engelli binici). Hareket hızı, adım uzunluğu ve adım süresi video kamera ile ölçüldü. Hareketin adım sırası ve açısal hızı atalet sensörleri ile belirlendi. Tüm denemelerde ön ayakların kinematik hareketlerinde yürüyüş bakımından gruplar arasında bir fark belirlenmedi. Engelli ile birlikte yürümede ön ayaklarda açısal hızın anterior fazı dışında ($P<0.05$) sol ve sağ ön ayaklar arasında da uygulamalar arasında bir fark bulunmadı. Arka ayak veri seti yetersiz n sayısı nedeniyle istatistiksel olarak karşılaştırılmadı. Sonuç olarak, atalet sensör teknolojisi ponilerin kinematik hareketlerini belirlemede özellikle de sensör ön ayaklarda takılı ise kullanılabilir. Poniler doğal kinematik hareketlerini yüklerine bağlı olarak adapte edebilmektedirler.

Anahtar sözcükler: *Poni, Yürüme, Kinematik, At-destekli terapi, Hipoterapi, Atalet sensörü*

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INTRODUCTION

Equine-assisted therapy (hippotherapy) is a physical, occupational, speech, and psychological treatment strategy through horseback riding that stimulates patients to have better emotional response, and to improve the balancing and weight transfer between themselves and horses. This activity is advantageous for children with musculoskeletal abnormalities and movement control failure [1]. Ponies are usually used in this activity as their size is suitable for young patient. For the most effective result, a pony with good physical and mental status is essential as is awareness regarding their welfare.

Good balance and body communication between a horse and its rider improves the horse's performance and welfare, including decreasing of stress, frustration, risks of injuries, and accidents. Thus, an experienced rider positively affects the cooperation of the horse with regard to the temperament, experience, and physical abilities of the horse [2]. On the other hand, riders with poor balance and body control often cause discomfort and stress to the ridden horses, leading to poor performance by the animal [3]. Therefore, it is possible that the horses or ponies used for equine-assisted therapy may (or may not) be at risk of physical discomfort, and this may be a cause for concern as regards the welfare of the animal. However, to the authors' knowledge, this matter has never been investigated and resolved.

Subjective lameness evaluation by a trained equine veterinarian is a routine diagnostic technique for lameness; however, it is not always reliable due to bias and it is less sensitive than motion sensors, especially for detection of mild lameness [4]. Kinematic analysis has eventually been developed to measure gait and motion in human patients with musculoskeletal and neuromuscular problems for the better treatment decision making and result evaluation with qualitative and quantitative assessment. This method has been incessantly developed and also applied in animals such as dogs and horses. Inertial sensor technology has been recently developed for human and horse kinematic analysis using WIFI signals which would replace wire connection or cameras. It enables objective evaluation by data collection and analysis as the horse walks on the ground [4]. Therefore, this technique is potentially beneficial for studying pony movement when it is being mounted by various types of riders including riders with typical development (normal rider) and those with physical disabilities (disabled rider). Therefore, the aim of the present study was to assess the feasibility of using inertial sensor technology to analyze ponies' kinematic motion at walking gait without riders, with normal riders, and with disabled riders.

MATERIAL and METHODS

The study received ethical approval from the ethics committee of the Faculty of Veterinary Medicine and the Faculty of Associated Medical Sciences, Chiang Mai University.

Animals

Ten (7 geldings and 3 mares) ponies (one from the Faculty of Veterinary Medicine, Chiang Mai University, 2 ponies from Laddaland Equestrian Club, and 7 ponies from the Pack Squadron, Chiang Mai) that had had previous equine-assisted therapy (EAT) experience were included in this study. All the ponies were healthy and had no history of illness in the previous 6 months, and were not lame, based on the results of subjective lameness evaluation before the study. The mean ± standard deviation (SD) age of these ponies was 13±3.43 years; the bodyweight (BW) was 295±30.66 kg; and the height was 136.2±8.95 cm. The ponies were led by their familiar handlers. Their temperament and performance were also observed during the course to be aware of any possible danger to both riders and ponies. Ponies with poor temperament status and unpleasant behaviors, including kicking, bucking, biting, reluctance to walk, and other aggressions, on the study day were temporarily excluded. Ponies that were temporarily excluded 3 times were permanently excluded from the study as were ponies that had any signs of illness or lameness during the course.

Riders

Two brothers of ages 9 and 14, with weight 27.5±0.71 kg and height 137.5±10.61 cm, were the riders. The 9-year-old rider was a child with typical development (normal rider) and the 14-year-old rider was one who had a physical disability from cerebral palsy with spastic diplegia (disabled rider) who suffered from balancing and body movement problems. Both riders wore equestrian helmets and safety vests every time they were on horseback.

Preparation of Horses

The ponies were tacked with their own set of riding equipment which consisted of a halter for the horse, both-side-restrained leashes, and a saddle. The adhesive tape was applied around the legs at positions that enabled the equipping of the inertial sensors. A pony equipped for forelimb analysis is shown in *Fig. 1*. The horse was leashed on both sides in this study because of the result obtained in the pilot study which revealed that handler being on one side had an effect on the kinematic results generated by the inertial sensor. The equipped ponies were warmed up by leading them to walk for 5 min and rest for 5 min before the study.

Each pony was instrumented with five inertial sensors (size 36 mm × 15 mm × 46.5 mm and weight 30 g; *Fig. 2)* which had a three-axial accelerometer, a gyroscope, and a magnetometer. For forelimb kinematic analysis, the sensors were placed, as shown in *Fig. 3*, at the following positions: (1) withers; (2-3) cranial aspect of mid-radius

Fig 1. Equipped pony with a halter, both-side leashes, and a saddle. The five inertial sensors (STT-IBS, STT Systems, Spain) were attached at the forelimbs and the withers to prepare the pony for forelimb kinematic data collection

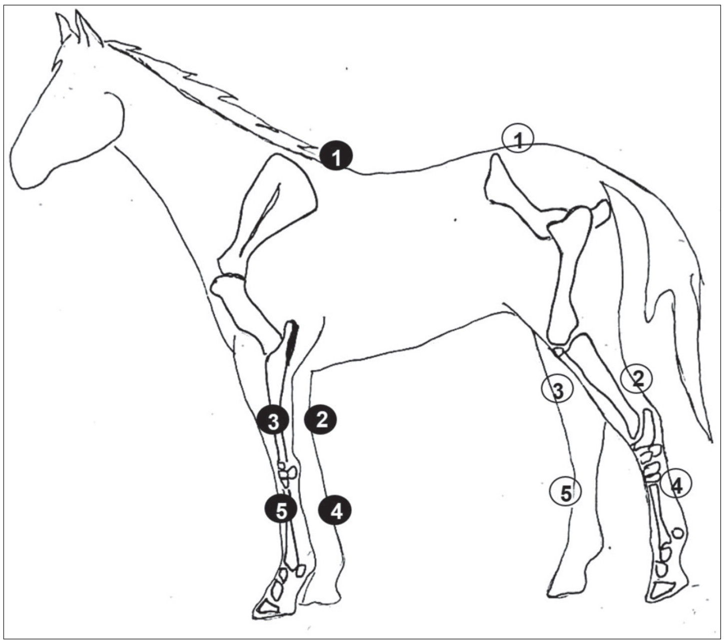

Fig 3. Schematic representation of the position of the inertial sensor in the forelimb and the hindlimb. Forelimb: withers (1), cranial aspect of mid-radius at both legs (2-3), and dorsal aspect of mid-metacarpus at both legs (4-5). Hindlimb: tuber sacrale (1), cranial aspect of mid-tibia at both legs (2-3), and dorsal aspect of mid-metatarsus at both legs (4-5)

at both legs; and (4-5) both the dorsal aspects of mid-metacarpus at both legs. For the hindlimb analysis, the sensors were placed at the following positions: (1) tuber sacrale; (2-3) cranial aspect of mid-tibia at both legs; and (4-5) both the dorsal aspects of mid-metatarsus at both legs. All the sensors were manipulated by the same person to ensure consistency throughout the study. The inertial sensors were placed initially for the forelimb analysis and then changed to the hindlimb afterward.

Fig 2. Examples of inertial sensors (STT-IBS, STT Systems, Spain)

Inertial Sensor Configuration

To set up the inertial sensors, a portable personal computer (laptop) with the suitable inertial software (STT Systems, Spain) was connected to the sensors via Bluetooth technology. The position of each sensor fixed on the pony's body was indicated and paired for their reference by the software. During walking, the movement of the sensors to their referred sensor was recorded and automatically quantified. A validity test of the sensors was performed to verify the accuracy of the data acquired *(Fig. 4)*. Upon using two inertial sensors placed at mid-radius and mid metacarpus with a 90-degree-flexed carpus, it was observed that the equipment measured the carpal angle at 90±2 degrees.

Walking Course Pattern

Five cone markers were placed every 5 m along the 20-meter-straight track *(Fig. 5)*. A walking course for the ponies for each intervention consisted of two round trips of this track. The first round consisted of two trials (departure and return) for the forelimb data set, and these were repeated in the second round for the hindlimb. The ponies were led straight from the first cone marker, made to pass the 20-meter-point, and then made to take a U-turn and walk straight back to the initial point *(Fig. 6)*. The data retrieved during the U-turn point were excluded.

Video Camera Setup

A digital video camera (EOS 70D Digital SLR Camera CANON®, 25 Hz frame rate, shutter speed 1:4000) was used for measuring the movement speed and the stride length. A camera monitor was set up to cover 10 m of the third and the fifth cone markers, with the height of the lens at 1.2 m and without magnification.

The movement speed was defined as the distance of the pony movement in one second. A stride consisted of a cycle of one hoof (this study observed the right forehoof

Fig 4. Validation test of the inertial sensor (Note that a book was applied as the reference for 90-degree flexion)

and the left forehoof during departure and return, respectively) movement completed when it regained the initial position. The stride length was the average distance of each pony stride calculated by the distance of the walking track (10 m) divided by the number of strides within the 10-m track. The stride duration was defined as the duration since one hoof lifted up from the ground till it regained its position on the ground.

Interventions

Each pony was assigned three interventions in random order and allowed at least a 5-min rest before starting the next intervention. The three interventions comprised walking with no rider, walking with a normal rider, and walking with a disabled rider.

Data Collection

Each data set was collected in duplicate. The data obtained by body-mounting the sensors were transmitted using wireless technology at 125-250 Hz in real time to a portable computer.

The parameters of each intervention from the sensors were the range of motion and the angular velocities (anterior and posterior) obtained from at least six complete strides.

The ranges of motion *(Fig. 7)* consisted of the following: (1) the arm swing range: the summation of the forward-moving and backward-moving angles from its referral line, which is the imaginary line drawn from the tip of the dorsal spinous process to the middle of the antebrachium when the pony is standing square; (2) the knee range: the summation of the forward-moving and backward-moving angles from its referral line, which is the imaginary line drawn from the middle of the antebrachium to the middle of metacarpus when the pony is standing square; (3) the thigh swing range: the summation of the forward-moving and backward moving angles from its referral line, which is the imaginary line drawn from the tuber sacrale to the middle of tibia when the pony is standing square; and (4) the hock range: the summation of the forward-moving and backward moving angles from its referral line, which is the imaginary line drawn from the middle of tibia to the middle of metatarsus.

Angular velocity is defined as the change in angular displacement per second. The angular velocity was also measured in the anterior and the posterior phases. In the anterior phase, the angular velocity was considered as the velocity of the angular changes when the limb moved forward from the vertical lines, and in the posterior phase, the angular velocity was considered as the velocity of the angular changes when the limb moved backward from the vertical lines.

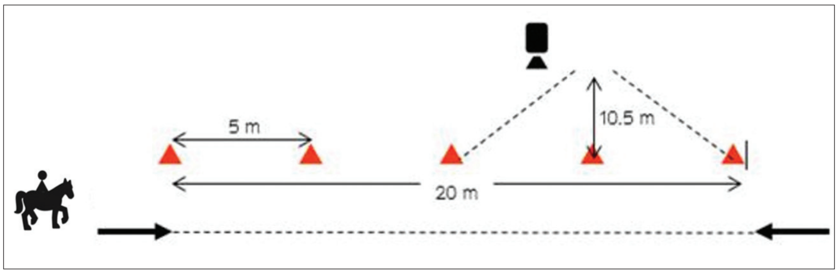

Fig 5. Walking track designed for the experiment

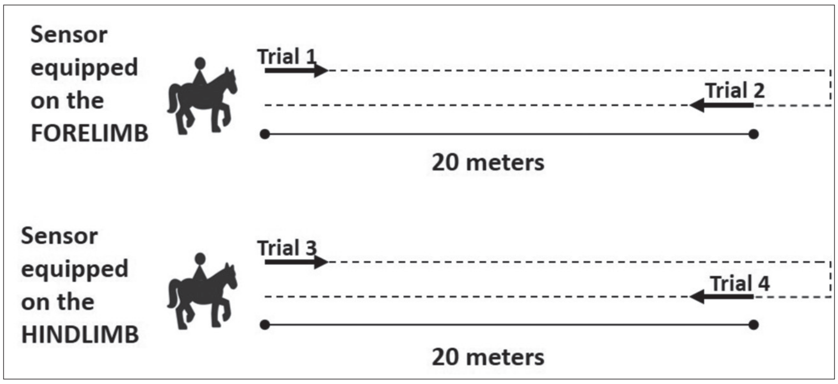

Fig 6. Horses' walking pattern for each intervention

Statistical Analysis

The speed, stride length, stride duration, and forelimb ranges of motion, as well as the angular velocities were

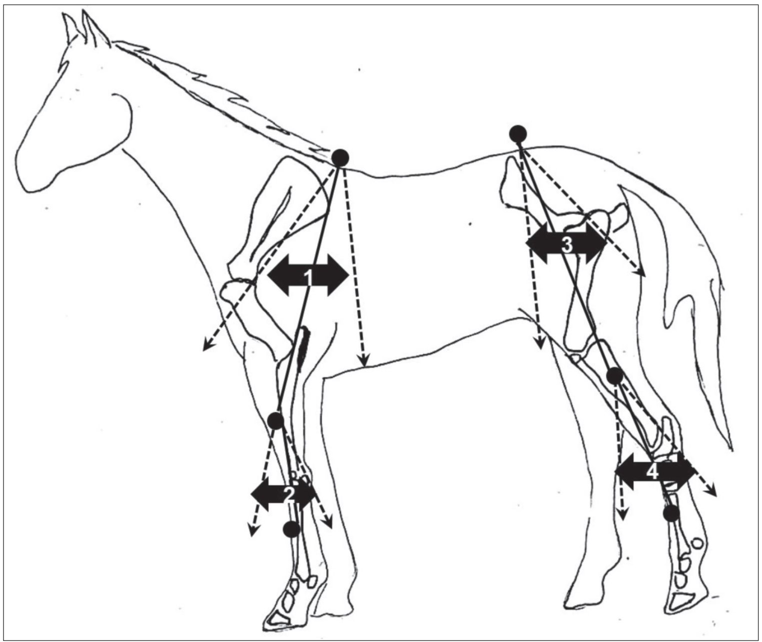

Fig 7. Schematic presentation of the range of motion of (1) arm swing range, (2) knee range, (3) thigh swing range, and (4) hock range. The front dashed line indicates the anterior phase and the back one denotes the posterior phase of each location

compared between the three interventions using repeated-measures analysis of variance (ANOVA) with the Tukey-Kramer's multiple comparison test. The ranges of motion and the angular velocities between the left and the right legs were compared using paired Student *t*-test. A P-value <0.05 was considered to be of statistical significance. The statistics were analyzed using the RStudio Version 0.98.501 software (RStudio, Boston).

RESULTS

The forelimb data were collected from all of the 10 ponies in this experiment. However, the hindlimb data could be obtained only from three ponies because seven ponies were very uncomfortable with attaching the devices to their hind legs and so, it was considered too dangerous for the riders. Therefore, the hindlimb ranges of motion and angular velocities were only descriptively analyzed. They could not be statistically compared between interventions and sides due to insufficient "n" number.

***Table 1.** Mean ± Standard Deviation for Movement Speed, Stride Length, and Stride Duration Compared between Walking without Rider (no rider), with a Rider with Typical Development (normal rider), and with a Rider with CP Spastic Diplegia (disabled rider)*

Parameter	Intervention of Ponies		
	No Rider	**Normal Rider**	**Disabled Rider**
Speed (m/s)	1.20±0.15	1.17±0.15	1.12±0.15
Stride length (cm)	1.44±0.17	1.44±0.17	1.41±0.16
Stride duration (s)	1.21±0.13	1.25±0.12	1.24±0.12

n=10; P>0.05 for each parameter between interventions

Overall, the movement speed of each intervention, as well as the stride length and duration are shown in *Table 1.* There was no significant difference in the movement speed, stride length, and stride duration between interventions.

The results (mean ± standard deviation of the ranges of motion and angular velocities of the forelimbs are shown in *Fig. 8-13*. The summary of the kinematic motion values (mean ± standard deviation and range) in ponies walking with no rider is shown in *Table 2*.

Ponies walking with both types of riders had no statistically significant differences in the ranges and angular velocities

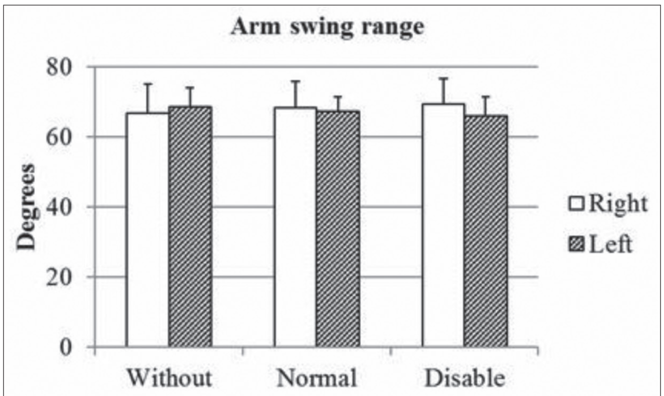

Fig 8. Means of the arm swing range compared between ponies walking with no rider (without), walking with a rider with typical development (normal rider), and walking with a rider with CP spastic diplegia (disabled rider) (n=10). The white bars represent the results from the right limb and the patterned bars represent the results from the left limb. Standard deviations are presented as T bars on the bar graphs. Significance is denoted as *P<0.05

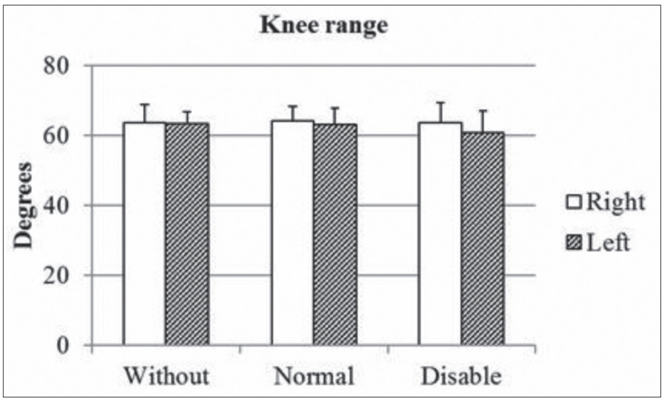

Fig 9. Means of the knee swing range compared between ponies walking with no rider (without), walking with a rider with typical development (normal rider), and walking with a rider with CP spastic diplegia (disabled rider) (n=10). The white bars represent the results from the right limb and the patterned bars represent the results from the left limb. Standard deviations are presented as T bars on the bar graphs. Significance is denoted as *P<0.05

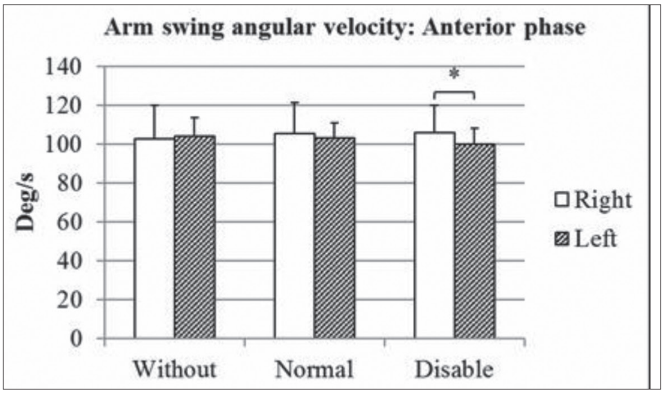

Fig 10. Means of the arm swing angular velocity (anterior phase) compared between ponies walking with no rider (without), walking with a rider with typical development (normal rider), and walking with a rider with CP spastic diplegia (disabled rider) (n=10). The white bars represent the results from the right limb and the patterned bars represent the results from the left limb. Standard deviations are presented as T bars on the bar graphs. Significance is denoted as *P<0.05

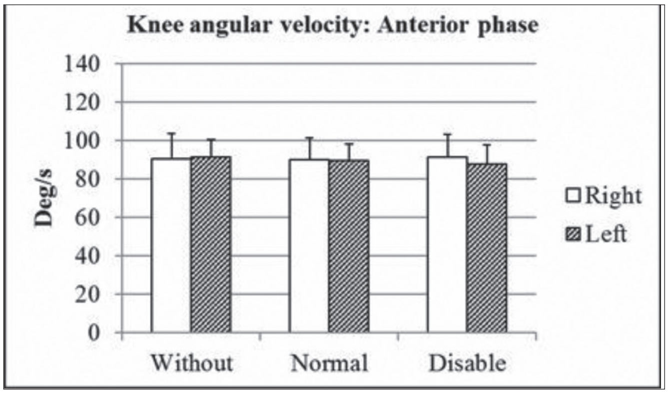

Fig 11. Means of the knee angular velocity (anterior phase) compared between ponies walking with no rider (without), walking with a rider with typical development (normal rider), and walking with a rider with CP spastic diplegia (disabled rider) (n=10). The white bars represent the results from the right limb and the patterned bars represent the results from the left limb. Standard deviations are presented as T bars on the bar graphs. Significance is denoted as *P<0.05

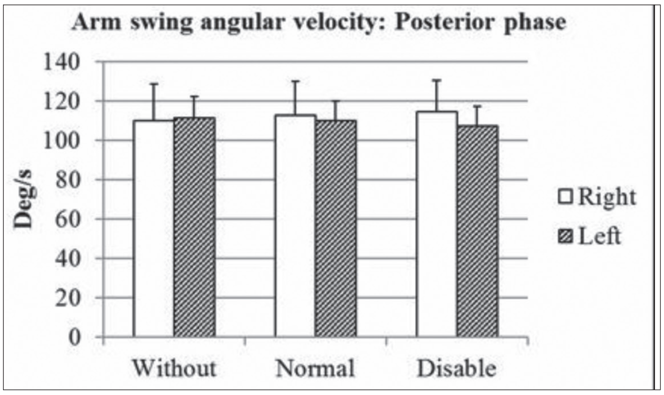

Fig 12. Means of the arm swing angular velocity (posterior phase) compared between ponies walking with no rider (without), walking with a rider with typical development (normal rider), and walking with a rider with CP spastic diplegia (disabled rider) (n=10). The white bars represent the results from the right limb and the patterned bars represent the results from the left limb. Standard deviations are presented as T bars on the bar graphs. Significance is denoted as *P<0.05

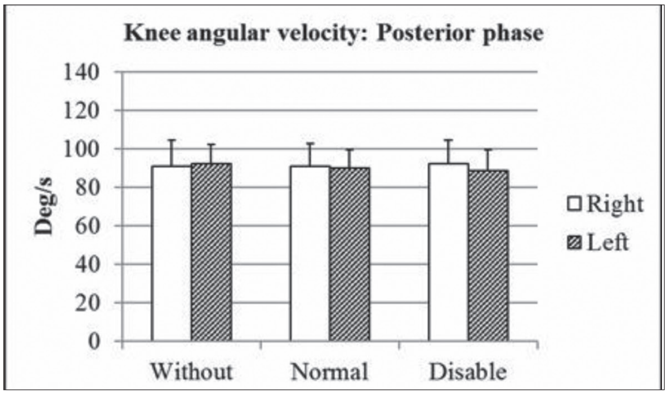

Fig 13. Means of the knee angular velocity (posterior phase) compared between ponies walking with no rider (without), walking with a rider with typical development (normal rider), and walking with a rider with CP spastic diplegia (disabled rider) (n=10). The white bars represent the results from the right limb and the patterned bars represent the results from the left limb. Standard deviations are presented as T bars on the bar graphs. Significance is denoted as *P<0.05

of the forelimbs compared to no-rider ponies. Similar results were obtained when a comparison was made between the left and the right forelimbs except in the case of the anterior phase of the angular velocity of the arm when walking with the disabled rider, in which the left side had a lower angular velocity than the right *(Fig. 10)*.

The results, including the mean and the standard deviation of the hindlimb ranges of motion and angular velocities, are shown in *Table 3* and *Table 4* for thigh and hock, respectively. It can be observed that the left thigh had a greater swing range than the right *(Table 3)*. On the other hand, the left hock range and the angular velocity were lower than the right hock range and the angular velocity *(Table 4)*.

DISCUSSION

This is the first study in which the kinematic motion of ponies for equine-assisted therapy (EAT) was evaluated with regard to the walking gait by applying the inertial sensor technology. The inertial sensor technique has been in use for equine motion analysis, especially in the analysis of the trotting gait with the aims of improving sports performance and fine detection of lameness [4] as well as studying the differences in motion between types of horses [5]. Inertial sensor technology is highly sensitive and accurate with quantitative data, and is suitable for detection of even the slightest asymmetry in movement [6].

The major components of gait speed are stride frequency and stride length. Stride length has a positive relation with the speed of gait [7]. In the present study, the ponies in all the interventions were allowed to walk in their comfortable movement speed. According to the results, loading the ponies with riders did not influence the movement speed, stride duration, or stride length. This is in accordance with the findings of a previous study, a study by Sloet et al.[8] who found that the stride duration in nine Dutch Warmblood horses walking on a treadmill did not differ significantly between being mounted, or loaded, and unloaded. Gottlieb et al.[9] also found no differences in the stride length between horses whether or not they were pulling a load. This could imply that the horses are capable of maintaining their natural speed and stride during work.

Range of motion and angular velocity are important factors of normal limb movement. Horses or ponies that have a normal range of motion and angular velocity in all articular joints would have comfortable motion. This study, unfortunately, could not measure these parameters in every joint due to the limitation with regard to number of sensors. However, the experiment was designed for monitoring at positions that could be most representative of the limb movement. There were no statistically significant differences found in the ranges of motion and angular velocities of arm swing and knee between the three interventions in this present study. This might be taken to imply that loading and type of load do not effect forelimb movement. These results are in accordance with the findings of Miró et al.[10] who reported no significant differences between the ranges of motion of shoulder, elbow, and carpal joints when the horse was handled while walking or was cart-driven in the walking gait. However, based on the findings of this study, it is too early to state that the ponies are capable of maintaining their forelimb kinematic motion during EAT working because not every joint was monitored. It has also been reported by a previous study that there was more fetlock extension while the horse was being mounted to walk [8]. Moreover, significant differences in the anterior phase of arm swing angular velocities were detected in this study between the left and the right limbs when the ponies were ridden by a disabled rider.

Table 2. *Summary of Kinematic Motion Values (mean ± standard deviation and range) in Ponies Walking with No Rider Using Inertial Sensor Technology*

Parameter		Limb	
		Right	Left
Forelimb (n=10)			
Arm swing range (degree)		66.85±8.35 (47.66-74.38)	68.49±5.67 (60.01-79.93)
Arm swing angular velocity (degree/s)	Anterior phase	102.94±16.99 (66.52-124.46)	104.40±9.40 (86.98-117.64)
	Posterior phase	110.30±18.47 (70.26-131.26)	111.67±10.91 (90.02-123.20)
Knee range (degree)		63.61±5.28 (56.60-71.45)	63.35±3.52 (54.98-68.17)
Knee angular velocity (degree/s)	Anterior phase	90.49±13.36 (71.17-106.22)	91.33±9.09 (76.68-101.60)
	Posterior phase	91.19±13.58 (70.16-107.34)	92.35±10.27 (76.88-103.90)
Hindlimb (n=3)			
Thigh swing range (degree)		36.40±2.63 (34.15-39.29)	47.01±5.48 (40.90-51.48)
Thigh swing angular velocity (degree/s)	Anterior phase	47.70±5.54 (43.14-53.87)	71.82±7.38 (65.29-79.84)
	Posterior phase	53.54±6.57 (48.49-60.96)	76.81±8.77 (68.55-86.02)
Hock range (degree)		43.38±3.81 (40.07-47.55)	36.77±4.97 (31.49-41.36)
Hock angular velocity (degree/s)	Anterior phase	57.49±4.14 (55.06-62.28)	39.41±9.32 (28.67-45.36)
	Posterior phase	50.21±3.13 (Range: 46.66-52.56)	35.31±8.00 (Range: 26.49-42.08)

Healthy horses usually have a symmetrical kinematic motion. Low angular velocity at the anterior phase of the left arm when walking with a disabled rider might indicate motion compensation to the imbalanced rider. Disabled riders cannot balance their weight transfer and usually shift their weight to the left side, so the ponies try to maintain the range of motion by increasing the angular velocity in the anterior phase of the opposite leg.

Asymmetrical range of motion between the left and the right hindlimbs was observed. Although the data came from only three ponies and could not be confirmed statistically, the explanation of this might be as follows: improper sensor position, the animal's preference of side, or subclinical lameness. In the author's opinion, as the sensors were placed in the same manner as in the case of

Table 3. *Ranges of Motion and Angular Velocities of Thigh of Hindlimb*

Pony No.	Thigh Swing Range						Thigh Swing Angular Velocity											
							Posterior Phase						Anterior Phase					
	Right			Left			Right			Left			Right			Left		
	W	N	D	W	N	D	W	N	D	W	N	D	W	N	D	W	N	D
8	39.3	40.1	38.8	51.5	46.0	43.6	51.2	54.8	47.8	68.6	65.0	59.6	46.1	49.9	42.6	65.3	61.1	55.9
9	34.2	33.3	34.7	40.9	42.2	40.8	48.5	53.2	60.5	75.9	73.6	72.6	43.1	47.1	53.4	70.3	68.4	66.6
10	35.8	36.0	35.2	48.7	48.5	48.9	61.0	63.3	59.9	86.0	88.2	89.3	53.9	56.9	52.8	79.8	81.7	82.3
Mean	36.4	36.5	36.2	47.0	45.6	44.5	53.5	57.1	56.1	76.8	75.6	73.8	47.7	51.3	49.6	71.8	70.4	68.3
SD	2.6	3.4	2.2	5.5	3.1	4.1	6.6	5.5	7.1	8.8	11.7	14.9	5.5	5.1	6.1	7.4	10.4	13.3

*n = 3; **W** = walking with no rider, **N** = walking with a rider with typical development (normal rider), and **D** = walking with a rider with CP spastic diplegia (disabled rider)*

Table 4. *Ranges of motion and angular velocities of hock*

Pony No.	Hock Range						Hock Angular Velocity											
							Posterior Phase						Anterior Phase					
	Right			Left			Right			Left			Right			Left		
	W	N	D	W	N	D	W	N	D	W	N	D	W	N	D	W	N	D
8	47.6	49.5	48.5	41.4	45.1	45.3	51.4	53.6	44.7	42.1	49.7	46.8	55.1	55.2	49.2	45.4	53.2	51.8
9	42.5	45.4	42.9	31.5	35.4	37.5	52.6	53.7	49.9	26.5	30.6	35.9	62.3	63.5	57.6	28.7	38.8	42.4
10	40.1	40.6	41.0	37.5	36.0	36.0	46.7	48.0	40.3	37.4	35.4	20.8	55.1	55.2	42.8	44.2	37.9	19.3
Mean	43.4	45.2	44.1	36.8	38.8	39.6	50.2	51.7	45.0	35.3	38.6	34.5	57.5	58.0	49.9	39.4	43.3	37.9
SD	3.8	4.5	3.89	5.0	5.4	5.0	3.1	3.2	4.8	8.0	10.0	13.1	4.1	4.8	7.5	9.3	8.6	16.7

n = 3; ***W*** *= walking with no rider,* ***N*** *= walking with a rider with typical development (normal rider), and* ***D*** *= walking with a rider with CP spastic diplegia (disabled rider)*

the forelimbs, it is unlikely to cause this difference. Also, the validity test with the equipment had shown reliable results. Limb preference exists in horses. Siniscalchi et al.[11] found that limb preference in horses is task dependent. In addition, horses, including ones that are used in EAT, are usually trained to be leashed and mounted on the left side, which might explain the greater swing range at the left than the right thigh, but this does not explain the lower hock swing range at the left. Another possible reason could be that the ponies had unobservable mild lameness, such as a subclinical joint problem or chronic osteoarthritis, which results in an unequal swing range of the two limbs. McCracken et al.[4] reported that objective lameness evaluation using an inertial sensor system would be able to detect lower levels of lameness compared to subjective lameness evaluation.

The limitations of the present study are as follows: (1) insufficient number of sensors, causing inability to measure the kinematic motion of all the joints at the forelimbs and the hindlimbs at the same time; (2) insufficient number of ponies that cooperated in the hindlimb study. For further studies, the authors suggest careful selection of ponies and increased numbers of both ponies and sensors.

This study showed that inertial sensor technology is feasible for use on pony kinematic analysis, especially when the sensors are attached to the forelimbs. There were no significant differences in any of the kinematic motions of ponies at walking gait between the different interventions except in the case of the anterior phase of the angular velocity of the arm when compared between the left and the right when walking with a disabled rider. It was supposed that the ponies may modify the natural kinematic motion when walking with a load.

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