THE EFFECT OF HIP JOINT MUSCLE STRENGTH AND SIZE ON HIP JOINT ANGULAR VELOCITY DURING 110 M HURDLING MOTION

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The purpose of this study was to investigate the effect of hip joint flexor/extensor strength and size on hip joint angular velocity during 110 m hurdling motion. To achieve this goal, we determined hip joint angular velocity during hurdling motion with high speed camera. We also measured isokinetic hip joint torque with a dynamometer, and measured the muscle volume of the psoas major muscle and hamstrings of the lead leg side with MRI. There were significant correlations between isokinetic hip joint flexor torque at 0.52 and 1.05 rad/s and hip joint flexion angular velocity ($p = 0.04$ and $p = 0.02$, respectively). There were no statistically significant correlations between muscle volume and joint angular velocity. These results suggested that hip joint flexor strength is possibly an important factor to swing up the lead leg quickly during hurdling motion.

KEYWORDS: psoas major muscle, hamstrings, isokinetic contraction, sprint

INTRODUCTION:

Sprint hurdle races, i.e., men's 110 m hurdles, differ from other sprint events in that obstacles are placed on the running lane. The height of the obstacles is 1.067 m in men's 110 m hurdles. In these sprint hurdle races, hurdlers need to possess two types of techniques, i.e., sprint technique and hurdling technique. Therefore, hurdlers need to improve both ability of sprinting and hurdling to shorten the finish time.

Hurdling technique include motions of take-off, flight and clearance, and landing. In the flight and clearance motions, hurdlers swing up and down the leg to clear the hurdles with the hip flexion and extension. At the same time, hurdlers extend, abduct and supinate the other leg after taking off, in addition to extending and bending the knee joint. The former leg is the lead leg and the latter leg is the trail leg. Hurdlers have a fixed lead leg and trail leg to clear the hurdles.

According to preceding studies, there were correlations between isokinetic hip joint flexor/extensor strength and 15, 35, 50 and 100m sprint time (Copaver et al., 2012; Dowson et al., 1998). In terms of muscles of the lower body, researchers reported that hamstrings (m. semimembranosus, m. semitendinosus and m. biceps femoris) are important in order to improve running speed (Mero & Komi, 1987; Mero et al., 1992). In addition, several preceding studies indicated that hip flexor muscles (e.g., psoas major muscle) were also important to improve running speed (Mero & Komi, 1987; Deane et al., 2005). Therefore, in the hurdlers those hip joint strength and muscles are crucial to increase the sprinting speed.

On the other hand, several previous studies investigated kinematic and kinetic. parameters in the hurdling motion (Amara et al., 2017; Coh et al., 2003; Salo & Grimshaw, 1998). While several studies have examined the hip musculature in the context of sprinting, few studies have examined this in the context of hurdling. Therefore, the purpose of this study was to investigate the effect of hip joint flexor and extensor strength and muscle size on hurdling motion. In particular, we focused on hip joint angular velocity in hurdle clearance.

METHODS:

Participants: 6 male collegiate hurdlers (Age: 20.7 ± 1.4 years; 1.78 ± 0.03 m; 68.43 ± 7.62 kg; 110 m hurdle personal record: 14.66 ± 0.59 s) participated in this experiment. All subjects had achieved the entry standard of the 94th Kansai University Championships (Men's 110 m hurdle: 15.30 s).

Hip Joint Angular Velocity: Participants performed running from crouching start over five hurdles placed following the competition rule. Each hurdler completed two repetitions. To determine the kinematic parameters, we used a high-speed camera (HAS-L2, DITECT. 300Hz). The camera was fixed at the height of 1.13 m, and was placed 28 m apart from the first lane of the track at the right angle (Fig. 1). The view covered the take-off and landing points of the third hurdle. To determine the position coordinate of anatomical landmarks, we used two-dimensional actual length conversion procedure in the sagittal plane with 2D motion analysis system (Frame-DIAS V, DKH). To determine the position coordinate of the body, we digitized seven markers attached to the landmarks of the lead leg side of the body (Fig. 2). From the joint of position coordinate, we determined hip joint angle and angular velocity. To determine the peak value of hip joint flexion and extension angular velocity, we set the analysis range from landing of the take-off leg (trail leg) to landing of the lead leg.

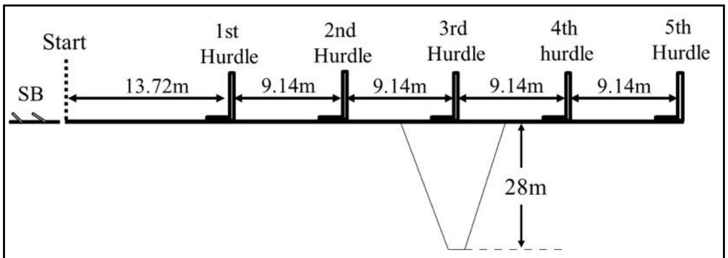

Figure 1. Experimental setup

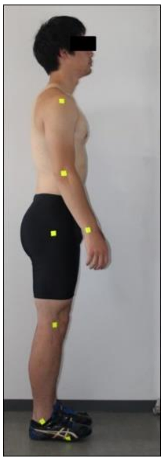

Figure 2. Marker set: markers were attached at the wrist, elbow, shoulder, greater trochanter, knee, ankle and 5th metatarsal head.

Isokinetic Hip Joint Torque: A dynamometer (System 4 ProTM; Biodex Medical Systems) was used to determine isokinetic hip joint torque. In accordance with previous studies (Dowson et al., 1998), all participants performed flexor/extensor isokinetic contraction at an angular speed of 0.52, 1.05 and 2.09 rad/s (30, 60 and 120 deg/s). The peak value of hip joint torque was determined as the highest hip joint flexor and extensor torque obtained during the three repetitions. The coefficient of variation of hip joint flexor and extensor peak torque was less than 10%.

Muscle Volume: Magnetic resonance imaging was used to determine the muscle volume of the psoas major (PM) muscle of the lead leg and hamstrings (HAM) of the lead leg. A 1.5 T MRI scanner (Signa HDxt 1.5 T, GE MEDICAL SYSTEM NETWORK) was used to acquire slices from the first cervical vertebra to the malleolus lateralis using an 8-channel body array coil. The scanning was performed with a conventional T1-weighted fast spin-echo sequence with an echo time/repetition time of 7 msec/respiration, slice thickness of 5 mm and pixel size of 384 × 384 mm. We used analysis software (OsiriX Lite 8.5.1; Pixmeo) to trace the area of each cross section of PM and HAM, and calculated the volume using trapezoidal integral.

Statistical analysis: Pearson correlation test was performed to determine the correlation between the hip joint flexor muscle volume and torque and hip joint flexion angular velocity, hip joint extensor muscle volume and torque and hip joint extension angular velocity. The level of significance was set at $p < 0.05$. In addition, according to Guilford's Rule of Thumb, we determined the size of the correlation: negligible, $r < 0.30$; low positive, $0.30 < r < 0.50$; moderate positive, $0.50 < r < 0.70$; high positive, $0.70 < r < 0.90$; very high positive, $0.90 < r$.

RESULTS: There were statistically significant correlation between isokinetic hip joint flexor torque at 0.52 and 1.05 rad/s (30 and 60 deg/s) and hip joint flexion angular velocity ($p = 0.04$ and $p = 0.02$, respectively, Figure 3 and Table 1). There were no statistically significant correlation between muscle volume and joint angular velocity (Table 1).

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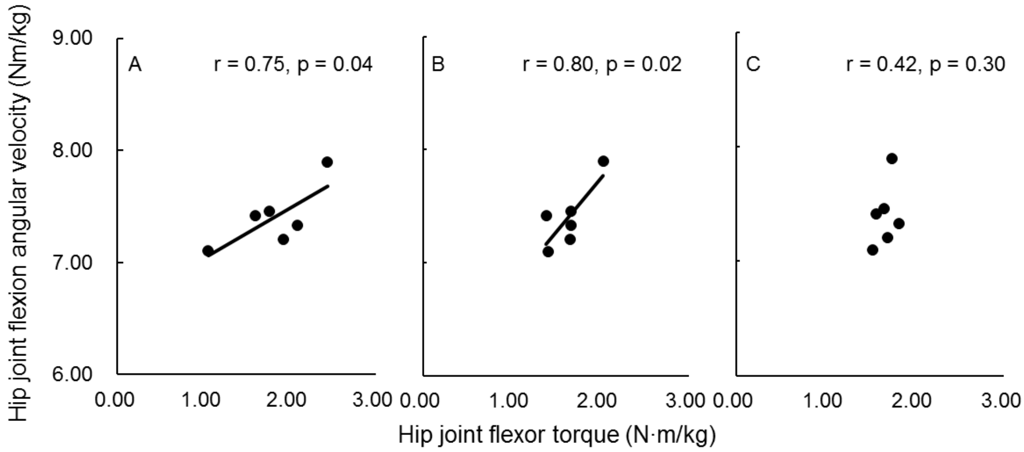

Note: A = 0.52 rad/s angular speed, B = 1.05 rad/s angular speed, C = 2.09 rad/s angular speed.

Figure 3: Correlations between isokinetic hip joint flexor torque and hip joint flexion angular velocity.

Table 1: Correlations between hip joint angular velocity, hip joint torque and muscle volume.

				M	SD	R	P
Angular Velocity [rad/s]			FLE	7.40	0.25		
[deg/s]				424	14.5		
			EXT	4.75	0.48		
				272	27.7		
KIN Hip Joint Torque	0.52	rad/s	FLE	1.81	0.43	0.75	**0.04***
[N·m/kg]	(30	deg/s)	EXT	3.14	0.81	0.25	0.56
	1.05	rad/s	FLE	1.64	0.21	0.80	**0.02***
	(60	deg/s)	EXT	3.17	0.87	0.15	0.72
	2.09	rad/s	FLE	1.67	0.10	0.42	0.30
	(120	deg/s)	EXT	3.13	0.83	0.21	0.62
Muscle Volume [cm^3/kg]			PM	4.52	0.75	0.28	0.51
			HAM	14.89	0.68	0.43	0.30

Note: M = mean, SD = standard deviation, R = correlation coefficient, P = p value, KIN =isokinetic contraction, FLE = flexion, EXT =extension, PM = psoas major muscle, HAM = hamstrings.

DISCUSSION: The purpose of this study was to investigate the effect of hip joint flexor and extensor strength and muscle size on hurdling motion. In terms of hip joint torque, the results showed that there were statistically significant correlations between isokinetic hip joint flexor torque at 0.52 and 1.05 rad/s (30 and 60 deg/s) of hip joint angular speed (p = 0.04 and p = 0.02 respectively, Figure 1). To clear the hurdles, hurdlers need to change horizontal movement of the centre of mass [COM] into the vertical direction. Swinging up the lead leg quickly makes it possible to change the horizontal movement of COM into vertical movement. The results suggested that greater hip joint flexor torque is one of the important factors, in order to change horizontal velocity to vertical velocity. Although there were statistically significant correlations between isokinetic hip joint flexor torque at two speed and hip joint angular speed, there were no significant correlations between isokinetic hip joint flexor torque at 2.09 rad/s (120 deg/s) and hip joint angular speed. In general, as muscle contraction speed becomes faster, muscle force becomes weaker. In this experiment result, hip joint

flexor strength at 2.09 rad/s was greater than at 1.05 rad/s. Hip joint angular velocity in actual hurdling motion was much faster than the speed of dynamometer used in this experiment. The results suggest the possibility that hurdlers have competition specific characteristics of muscle strength; that is, they can produce great hip joint flexor strength even at large contraction speed. On the other hand, there were no statistically significant correlations between isokinetic hip joint extensor torque at all angular speeds (Table 1). Since longer flight time is disadvantageous in terms of running speed, hurdlers need to shorten flight time. Therefore, it is important to swing down the lead leg for shortening flight time. Projectile motion is basically decided by initial velocity and launch angle. In addition, McDonald and Dapena (1991) found that angular momentum during interval running phase and flight phase was always negative (forward rotation). Because the body rotates in the forward direction after take-off, hurdlers need to generate hip joint extensor torque to swing down the lead leg.
In terms of hip joint muscles volume, the results showed that there were no statistically significant correlation between muscle volume and joint angular speed (Table 1). Hurdlers swing up and down the lead leg before and after clearing the hurdles. Shortening speed of muscles is determined by many factors (length of muscle fascicles, neural factors and fibre type). In addition, hip joint flexion angular velocity is a variable dependent on moment of inertia of body parts (McDonald & Dapena, 1991). This may have caused the results that the muscle volume of PM and HAM has weak direct effect on joint angular velocity during hurdling motion.

CONCLUSIONS: The purpose of this study was to investigate the effect of hip joint flexor and extensor strength and muscle size on hip joint angular velocity during hurdling motion. The results suggested that the hip joint flexor torque is a possibly important factor to swing up the lead leg quickly. However, hip joint flexor and extensor muscle sizes had no statistically significant relation with the hip joint angular velocity during hurdling motion. To shorten hurdling time, hurdlers may need to possess hip joint flexor strength. The results would be useful in the development of training programs to improve hurdle race performance in the future.

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