The Reaction Time of Mental Rotation Predicts Strain in Rugby Players

MINORU YAMADA, RPT¹⁾, DAISUKE MASTUMOTO, RPT²⁾

¹⁾Department of Human Health Sciences, Graduate School of Medicine, Kyoto University:
53 Kawahara-cho, Shogoin, Kyoto City, Kyoto 606-8503, Japan.

TEL: +81 75-751-3964, FAX: +81 75-751-3909, E-mail: yamada@hs.med.kyoto-u.ac.jp

²⁾Faculty of Health Science, Kio University

Abstract. [Purpose] This study investigated the relation between motor imagery and hamstring strain in rugby players. [Subjects] The participants of this study comprised 21 university rugby players (42 legs). [Methods] The motor imagery capacity of the subjects was evaluated using mental rotation and various motor exercises. The subjects were followed up 6 months after the measurements were taken, and the hamstring strain occurring in the intermittent period was investigated. [Results] Seven legs of 6 players (7/42, 16.7%) showed symptoms of hamstring strain within 6 months. In addition, all these subjects had medial hamstring injury that had occurred in a non-contact fashion. A significant difference was observed in the reaction time between the strain and non-strain groups for identifying photographs of the plantar view of the foot at an orientation of -90° . Furthermore, a cutoff value of 2.48 sec for this reaction time could predict hamstring strain by discriminant analysis. [Conclusion] Capacity of motor imagery influences the development of hamstring strain.

Key words: Hamstring strain, Mental rotation, Rugby

(This article was submitted Nov. 19, 2008, and was accepted Feb. 13, 2009)

INTRODUCTION

Many rugby and American football players receive hamstring strain and anterior cruciate ligament (ACL) injuries. The causes of many of these athletic injuries have been shown to be of a non-contact nature¹⁾. Therefore, many factors such as lack of flexibility, loss of muscle strength, imbalance of antagonists, muscle fatigue, and lack of sufficient warm-up exercises have been reported as causes of hamstring strain^{2–7)}. Although there have been many reports on the development of symptoms of hamstring strain, none of these studies have carried out cognitive neuroscience examinations. Sports such as rugby and American football demand a high level of physical performance. To achieve such high performance levels, not only motor function but also cognitive

function is required.

Motor imagery is a first-person image formed using somatosensory inputs rather than actual motor performance⁸⁾. Recently, reports have considered the relation between the improvement in the skill of sport performance and motor imagery. However, no reports have considered the relation between the generation of externally caused injuries and the capacity of motor imagery.

Mental rotation of a body part is a simple method of measuring a person's capacity of motor imagery. Mental rotation is the ability to mentally identify an object, which is presented in a rotated manner⁹⁾. Previous studies have reported activity in the cerebral motor-related area during mental rotation when subjects viewed a photograph of a hand^{10–14)}. This activity was the same as that observed during first-person motor imagery. This result suggests the

possibility that the function that mentally rotates the photograph of a body part could be a useful means of reinforcing simple motor imagery. It has been reported that patients with complex regional pain syndrome type 1 exhibit a notably longer reaction time when identifying a photograph depicting the affected side of their body than when identifying a photograph depicting the unaffected side of their body. This result suggested that motor imagery capacity is falling by the patients with complex regional pain syndrome type 1¹⁵⁾.

The purpose of this research was to measure the motor imagery capacity of rugby players' legs using mental rotation and to examine whether development of hamstring strain can be predicted.

SUBJECTS AND METHODS

Subjects

The participants of this study comprised 21 university level rugby players (21.3 ± 0.3 years old, mean $\pm$ SD), and both legs of each participant were analyzed in this study (42 legs). Written informed consents were obtained from each subject in accordance. The study used a cohort study design.

Methods

The mental rotation performed by the participants was measured using custom software on a personal computer. Photographs depicting the dorsal and plantar views of the right and left feet were displayed on a screen. Each photograph was then randomly rotated clockwise to 0° , 90° , -90° , and 180° , i.e., a total of 16 photographs were displayed in random order (Fig. 1). The subjects were shown the photographs and asked to identify the pictures as quickly as possible by using a fingertip to push a button to indicate "right foot" or "left foot" correctly, and the subjects' responses were then recorded. However, it did not accept moving a foot or seeing a foot at that time. The reaction time (msec) was defined as the time when the photograph is displayed until the time the subject pushes the button to record the response. In addition, measurement was once performed after the demonstration.

Motor function was measured by considering the H/Q ratio (ratio of the hamstring and quadriceps femoris), SLR angle (straight-leg-raising angle), and the center-of-gravity agitation in the one-leg standing position and that during a perpendicular

Fig. 1. Photographs of the foot in various orientations used for the mental rotation task

Dorsal view of the foot at the 4 angles of 0° , 90° , -90° , and 180° are depicted in the upper row from left to right. Plantar view of the foot at 0° , 90° , -90° , and 180° are shown from left to right in the lower row. The photographs shown depict only the right foot. In the experiment, images of the left foot at similar angles were also shown, i.e., the subjects were shown a total of 16 photographs.

jump performed using 1 leg.

CYBEX 770-NORM (CYBEX Japan) was used for measuring muscular power. The peak torque and power during the flexion and extension of the knee joint at $60^\circ/\text{sec}$ and $180^\circ/\text{sec}$ were measured. In order to prevent movement of the trunk or at the hip joint, the waist was fixed by a belt, and the subject was asked to grasp a handrail during the measurement. The subjects were asked to repeat the movement for 5 times with maximum effort, and the maximum value was considered as the central value. The ratio of the muscular power of the hamstring to that of the quadriceps femoris was computed using this central value (H/Q ratio). Further, the H/Q ratio was computed for 2 conditions each of torque and power ($60^\circ/\text{sec}$ and $180^\circ/\text{sec}$).

The SLR angle was measured when the subject remained in a supine position.

The subject stood on 1 leg, and the center-of-gravity agitation was measured for 30 sec by using a sampling frequency of 200 Hz in the gravicoder (G-550; Anima). For the measurement, the subject was asked to stand on 1 leg with arms folded. Each measurement was carried out 2 times for the following 2 conditions: eyes open and eyes closed.

The used index is the total locus length and the minimum value of 2 times of inside was used for it.

Table 1. Subject characteristics and measurement results

Characteristic		Strain group		Non-strain group		p value
		Average	SD	Average	SD	
Characteristic						
Height	(cm)	172.2	4.06	174.49	4.04	
Weight	(kg)	71.84	6.32	74.81	7.46	
BMI	(kg/m ²)	24.22	1.86	24.54	2.00	
Reaction time of mental rotation						
Dorsal view of the foot: 0°	(sec)	1.07	0.42	0.87	0.40	0.049
Dorsal view of the foot: 90°	(sec)	0.99	0.37	1.12	0.57	0.843
Dorsal view of the foot: -90°	(sec)	0.89	0.18	1.04	0.44	0.508
Dorsal view of the foot: 180°	(sec)	1.42	0.32	1.61	0.71	0.947
Plantar view of the foot: 0°	(sec)	2.05	0.75	1.66	0.72	0.243
Plantar view of the foot: 90°	(sec)	2.32	0.83	2.20	2.08	0.272
Plantar view of the foot: -90°	(sec)	2.72	0.68	1.90	0.98	0.008
Plantar view of the foot: 180°	(sec)	1.46	1.02	1.27	0.56	0.974
Motor function						
60° of H/Q ratio (torque)		0.63	0.07	0.60	0.10	0.383
60° of H/Q ratio (power)		0.91	0.57	0.64	0.13	0.255
180° of H/Q ratio (torque)		0.74	0.13	0.70	0.13	0.566
180° of H/Q ratio (power)		1.07	0.59	0.79	0.16	0.306
SLR angle	(degrees)	92.86	6.99	88.57	11.09	0.205
One-leg COG with eyes open	(mm)	99.60	17.88	121.91	30.77	0.085
One-leg COG with eyes closed	(mm)	190.16	39.82	246.24	78.36	0.030
Perpendicular jump on 1 leg	(cm)	25.43	3.41	22.30	3.74	0.053

The multi-jump tester (DKH) was used for the perpendicular jump on one leg. The measurement was performed twice and the maximum value was considered. For the measurement, the subject was asked to stand on 1 leg with arms folded.

Thereafter, the subjects were followed up for 6 months from the date of measurement to determine the existence of hamstring strain. The standard of judgment was considered as diagnosis of hamstring strain by a medical doctor. Therefore, when the subject experienced incongruity and pain in the leg, consultation to a medical institution was imposed.

The subjects were divided into 2 groups: subjects with and without hamstring strain. The Mann-Whitney test was used to compare the subject's (strain group and non-strain group) reaction time for the mental rotation of each photograph and the measurements of each motor function to examine the predictive validity of this study. Receiver-operated characteristic (ROC) curves were inspected to determine the cut-off points for each reaction time and each motor function test that best discriminated between subjects who did and did not have hamstring strain. Discriminant analysis was

performed in the variables whose area under curve was the largest. P values of less than 0.05 were considered statistically significant.

RESULTS

Seven legs assessed in 6 players (16.7%) showed symptoms of hamstring strain over 6 months. All the subjects had medial hamstring injury, which had occurred in a non-contact manner.

The results of each group are presented in Table 1. The significant differences between the strain group and the non-strain group were accepted with no indices of each motor function ($p > 0.05$). The strain group had a significantly longer mean reaction time for the 0° dorsal and -90° plantar views of the foot as compared with the non-strain group ($p < 0.05$). ROC curve analysis revealed that the reaction time for the -90° plantar view of the foot had the greatest the area under the curve (Table 2). Discriminate analysis showed that the cut-off point was 2.48 seconds for the reaction time of the -90° plantar view of the foot.

Table 2. Area under curve with the ROC curve of each index

	AUC
Reaction time of mental rotation	
Dorsal view of the foot: 0°	0.678
Dorsal view of the foot: 90°	0.411
Dorsal view of the foot: -90°	0.344
Dorsal view of the foot: 180°	0.450
Plantar view of the foot: 0°	0.667
Plantar view of the foot: 90°	0.594
Plantar view of the foot: -90°	0.812
Plantar view of the foot: 180°	0.528
Motor function	
60° of H/Q ratio (torque)	0.700
60° of H/Q ratio (power)	0.689
180° of H/Q ratio (torque)	0.628
180° of H/Q ratio (power)	0.667
SLR angle	0.700
One leg COG with eyes open	0.322
One leg COG with eyes closed	0.222
Perpendicular jump on 1 leg	0.758

AUC: Area under the curve.

DISCUSSION

In the mental rotation exercise with the photograph of a foot, motor imagery, which coincides the direction of the foot in a photograph with that of one's own foot, is performed. This motor imagery is used to identify whether the photograph depicts the left or right foot. Therefore, it is considered that the reaction time reflects motor imagery capacity¹⁵⁾. In this study, it was possible to predict hamstring strain by the reaction time for the -90° plantar view of the foot.

In order to match the direction of the -90° plantar view of the foot with that of one's own foot, extension and internal rotation of the hip joint and flexion of the knee joint are required. This position requires the excessive use of the medial hamstring, increasing the stress therein. Further, this position is similar to the leg movement while running when the trunk is tilted anteriorly. Although such an assumption is arguable, hamstring strain may have occurred in such a position. Thus, a player for whom motor imagery of this motion is difficult to achieve is considered to have a higher risk of hamstring strain. In addition, it is considered that the capacity for motor imagery capacity is low when there is a considerable difference between a motion recognized by the self and the actual motion.

No previous studies have reported the relation between motor performance and hamstring strain. The follow-up periods may not have taken the frequency of participation in the sport into consideration despite being conducted during the sport season. This may have applied a bias to the study of hamstring strain. In addition, few reports have predicted the occurrence of hamstring strain. Furthermore, there is no index for the prediction of hamstring strain. Thus, the function of cognitive neuroscience in the prediction of hamstring strain is a very valuable finding.

In rehabilitation-related research conducted in recent years, some studies have reported that physical function is improved by mental practice¹⁶⁻¹⁸⁾. Sport-related research has also reported that performance is improved by mental practice^{19,20)}. However, no reports suggest that prevention of injury is possible through mental practice. Therefore, further studies are necessary to pursue the possibility of injury prevention through mental practice.

REFERENCES

- 1) Bird YN, Waller AE, Marshall SW, et al.: The New Zealand rugby injury and performance project. *Br J Sports Med*, 1998, 32: 319-325.
- 2) Sutton G: Hamstrung by hamstring strains: a review of the literature. *J Orthop Sports Phys Ther*, 1984, 5: 184-195.
- 3) Bandy WD, Irion JM, Briggler M: The effect of time and frequency of static stretching on flexibility of the hamstring muscle. *Phys Ther*, 1997, 77: 1090-1096.
- 4) Malliaropoulos N, Papalexandris S, Papalada A, et al.: The role of stretching in rehabilitation of hamstring injuries: 80 athletes follow-up. *Med Sci Sports Exerc*, 2004, 36: 756-759.
- 5) Brooks JH, Fuller CW, Kemp SP, et al.: Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med*, 2006, 34, 1297-1306.
- 6) Orchard JW: Intrinsic and extrinsic risk factor for muscle strains in Australian football. *Am J Sports Med*, 2001, 29: 300-303.
- 7) Heiser TM, Weber J, Sullivan G, et al.: Prophylaxis and management of hamstring muscle injuries in intercollegiate football players. *Am J Sports Med*, 1984, 12: 368-370.
- 8) Dickstein R, Deutsch JE: Motor imagery in physical therapist practice. *Phys Ther*, 2007, 87: 942-953.
- 9) Persons LM: Integrating cognitive psychology, neurology and neuroimaging. *Acta Psychol*, 2001, 107: 155-181.
- 10) de Lange FP, Helmich PC, Toni I, et al.: Posture

- influences motor imagery: an fMRI study. *Neuroimage*, 2006, 33: 609–617.
- 11) Fazio M, Tinazzi M, Aglioti M, et al.: Selective impairment of hand mental rotation in patients with focal hand dystonia. *Brain*, 2006, 129: 47–54.
 - 12) Richter W, Somorjai R, Summers R, et al.: Motor area activity during mental rotation studied by time-resolved single trial fMRI. *J Cogn Neurosci*, 2000, 12: 310–320.
 - 13) Fiorio M, Tinazzi M, Ionta S, et al.: Mental rotation of body parts and non-corporeal objects in patients with idiopathic cervical dystonia. *Neuropsychologia*, 2007, 45: 2346–2354.
 - 14) Wolbers T, Weiller C, Büchel C: Contralateral coding of imaged body parts in the superior parietal lobe. *Cereb Cortex*, 2003, 13: 329–329.
 - 15) Moseley GL: Why do people with complex regional pain syndrome take longer to recognize their affected hand? *Neurology*, 2004, 62: 2182–2186.
 - 16) Cramer SC, Orr EL, Cohen MJ, et al.: Effects of motor imagery training after chronic, complete spinal cord injury. *Exp Brain Res*, 2007, 177: 233–242.
 - 17) Molder T: Motor imagery and action observation: cognitive tool for rehabilitation. *J Neural Trans*, 2007, 114: 1265–1278.
 - 18) Dickstein R, Deutsch JE: Motor imagery in physical therapist practice. *Phys Ther*, 2007, 87: 942–953.
 - 19) Brouzine M, Molinaro C: Mental imagery combined with physical practice of approach shots for golf beginners. *Percept Mot Skills*, 2005, 101: 203–211.
 - 20) Coelho RE, De Campos W, Da Silva SG, et al.: Imagery intervention in open and closed tennis motor skill performance. *Percept Mot Skills*, 2007, 105: 458–468.