Journal of Electromyography and Kinesiology 24 (2014) 271–276

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Effect of posterior cruciate ligament creep on muscular co-activation around knee: A pilot study

Xiangrong Cheng[a], Tailai Zhang[b], Xinhai Shan[a,*], Jingyuan Wang[a]

[a] Biomechanics Laboratory, College of Physical Education, Shandong Normal University, 88 Wenhua East Road, Jinan, Shandong 250014, China
[b] Biomechanics Laboratory, Shandong Research Center of Sports Science, Jinan 250000, China

ARTICLE INFO

Article history:
Received 6 June 2013
Received in revised form 15 December 2013
Accepted 15 January 2014

Keywords:
Posterior cruciate ligament
Creep
Muscle co-activation
Knee
Agonist
Antagonist

ABSTRACT

The effect of posterior cruciate ligament (PCL) on muscle co-activation (MCO) is not known though MCO has been extensively studied. The purpose of the study was to investigate the effect of PCL creep on MCO and on joint moment around the knee. Twelve males and twelve females volunteered for this study. PCL creep was estimated via tibial posterior displacement which was elicited by a 20 kg dumbbell hanged on horizontal shank near patella for 10 min. Electromyography activity from both rectus femoris and biceps femoris as well as muscle strength on the right thigh was recorded synchronically during knee isokinetic flexion–extension performance in speed of 60 deg/s as well as 120 deg/s on a dynamometer before and after PCL creep. A one-way ANOVA with repeated measures was used to evaluate the effect of creep, gender and speed. The results showed that significant tibial posterior displacement was found ($p = 0.01$) in both male and female groups. No significant increase of joint moment was found in flexion as well as in extension phase in both female and male groups. There was a significant effect of speed ($p = 0.036$) on joint moment in extension phase. Co-activation index (CI) decreased significantly ($p = 0.049$) in extension phase with a significant effect of gender ($p \leqslant 0.001$). It was concluded that creep developed in PCL due to static posterior load on the proximal tibia could significantly elicit the increase of the activation of agonist muscles but with no compensation from the antagonist in flexion as well as in extension phase. The creep significantly elicited the decrease of the antagonist–agonist CI in extension phase. MCO in females was reduced significantly in extension phase. It was suggested that PCL creep might be one of risk factors to the knee injury in sports activity.

1. Introduction

As a simultaneous activity of various muscles around a joint, muscle co-activation (MCO) has been widely studied through comparing Electromyography (EMG) values of muscles (Bobbert et al., 1987; Bosco and Viitasalo, 1982; Kellis, 1998; Knutson et al., 1994; Solomonow et al., 1987; Unnithan et al., 1996; Viitasalo et al., 1998; Voigt et al., 1995), which is usually represented as a myoelectric intensity rate of antagonist–agonist muscles for a special joint such as the knee (Masci et al., 2010).

A previous investigation found that MCO could be utilized as an indicator of neuromuscular adaptation (Ferris et al., 2006; Masci et al., 2010), which is thought to be linked to the underlying center nerve system (CNS) (Masci et al., 2010). When related to movement ability, the decrease of MCO is beneficial. The decrease of MCO may indicate the achievement of a motor skill through the progressive inhibition of muscular activity that is not related to the task (Basmajian, 1977) while the increase of MCO may mean the inefficiency of human movement (Falconer and Winter, 1985; Winter, 2005). It was confirmed that an athlete could decrease MCO around the knee and thus improve the jump ability after prolonged training (Masci et al., 2010).

However, the decrease of MCO is disadvantageous when related to joint injury. The decrease of MCO may be related to the increase of joint instability (Baratta et al., 1988; Hagood et al., 1990). Hagood et al. (1990) demonstrated a reduced antagonist MCO when the angular velocity decreased. Chu et al. (2003) pointed out that, since MCO would be decreased after anterior cruciate ligament (ACL) creep, ACL creep may expose the knee joint to be in risk of instability and potential injury especially for women. The increased risk of ligamentous injuries in women is postulated to be associated with their increased joint laxity (Acasuso-Diaz et al., 1993; Larsson et al., 1987). Chu et al. (2003) suggested that the myoelectric activation of agonists becomes larger after ACL creep while there is no compensation from antagonists, and

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[*] Corresponding author. Tel.: +86 13964086740; fax: +86 531 86182581.
E-mail address: xhshan_jn@aliyun.com (X. Shan).

http://dx.doi.org/10.1016/j.jelekin.2014.01.005
1050-6411/

furthermore, the muscle force could become larger because of lacking inhibition of reflexive arcs from cruciate ligament after ACL creep. Considering that there are two cruciate ligaments within the knee joint, the posterior cruciate ligament (PCL) creep may also make MCO decrease.

It seems imperative for us to investigate the relationship between PCL creep and the change of MCO. Several serious PCL injuries were reported to have PCL sustained loading in sports activity (Margheritini et al., 2002; Rosenthal et al., 2012). Besides, it was reported that ligamentous creep in lumbar spine is associated not only with a temporal mechanical laxity but also with the desensitization of the reflex arcs initiated by the mechanoreceptors in the ligament (Jackson et al., 2001; Solomonow et al., 1999). However, so far as we known, there is no corresponding investigation regarding the MCO change after PCL creep.

Therefore, the purpose of the study was to investigate the effect of PCL creep on MCO and on joint moment around the knee. Based on the findings of previous investigation, we hypothesized that after PCL creep: (1) there would be a significant decrease of MCO in knee flexion as well as in knee extension phase; (2) gender would have some effect on MCO with female becoming significantly lower than male; (3) high speed could elicit more decrease of MCO and (4) joint moment of the knee would increase both in female and male groups.

2. Materials and methods

2.1. Participants

Twenty-four participants (12 male and 12 female) were recruited from University student population to participate in the study which was approved by local ethical committee. The experiments took place in Shandong Normal University. Participants read and signed a consent form before participating in the study. Demographic information was collected using a questionnaire to screen for inclusion and exclusion criteria. Participants' age, weight, height, (mean (SD) [minimum–maximum]) were 22(2) [19–24] years, 76(16) [61–85] kg, 180(3) [170–192] cm for male; and 21(1) [20–22] years, 56(8) [51–65] kg, 164(5) [158–170] cm for female, respectively. Participants without current complaints of pain on the knee joint were included in the study. Exclusion criteria consisted of any uncorrectable knee pathology, history of knee surgery, current neurological disorder on lower extremity, consultation of a physician for the knee in the last year.

2.2. PCL creep estimation

Participants were seated on a chair and put the right leg on a stool with the knee straight (Fig. 1). The foot was put on another stool with the same height of the chair. A wood plate and a soft cushion together were put under thigh near the knee joint to adjust the thigh to be horizontal. A 20 kg dumbbell was hanged on the shank near patella for 10 min.

In order to estimate PCL creep via tibial posterior displacement, the downward vertical displacement was quantified by a precision stadiometer as proposed by Eklund and Corlett (1984). The modified custom stadiometer consisted of a wooden frame (Gerke et al., 2011), fixed on the back of chair. The measurement results of height (displacement) were demonstrated to be both reliable and valid (Gerke et al., 2011; Kanlayanaphotporn et al., 2002; Shan et al., 2012).

After a participant's shank was positioned on the stadiometer frame, a platform of the stadiometer was lowered at a point near the loading position until the shank was fully contacted. Then the investigator recorded stadiometer readings to test the vertical height displacement of the shank.

Fig. 1. An examplar subject with a 20 kg barbell during PCL creep in 10 min.

In order to eliminate the effect of elastic strain, the beginning of the creep was defined as 5 s after the load being applied (Chu et al., 2003; Shan et al., 2013). The initial shank height before loading was normalized to be zero.

2.3. EMG test

The rectus femoris and biceps femoris on the right thigh were selected to represent the Quadriceps (Quad) and Hamstring (Hams) (Chu et al., 2003). The skin overlying muscles on the right thigh was cleansed and lightly abraded with alcohol prep pads before EMG electrode attachment. The pre-gelled (Ag–AgCl) 5 cm diameter disposable electrodes were placed longitudinally over the muscle bellies with a 5 cm interelectrode distance (Chu et al., 2003). A reference electrode was placed on the right anterior superior iliac crest (Shan et al., 2013). The EMG signals were amplified (Biovision, Germany) × 1000 with a frequency bandpass of 10–500 Hz, 1 μV noise referred to input, and CMRR of 120 dB. The Input impedance was 10^{9} kΩ. The resulting signal was sampled at 1000 Hz via a 14-bit data acquisition system and stored for later processing.

2.4. Muscle strength test

The joint moment during knee flexion–extension was tested on a dynamometer (CON-TREX, Swiss). The EMG and moment signals were recorded synchronically.

A cycle included flexion and extension phases and was determined according to the joint moment curve. The flexion phase in one cycle in EMG signal was determined synchronically by the negative value of joint moment. Then the extension phase was determined by the positive value of joint moment (Fig. 2). The moment M was determined by the absolute top value during one phase.