THE ACUTE EFFECTS OF THE PREVENT INJURY ENHANCE PERFORMANCE PROGRAMME (PEP) ON ANTERIOR CRUCIATE LIGAMENT INJURY RISK FACTORS

Chris McCann and Sarah B Clarke

Carnegie Research Institute, Leeds Metropolitan University, Leeds, England

The purpose of this study was to determine the immediate effects the prevent injury enhance performance programme (PEP) had on lower extremity biomechanics in relation to anterior cruciate ligament (ACL) risk factors compared to when it was not performed. 8 healthy males were required to perform a number of drop rebound jumps as a task that mimicked the sudden deceleration seen during ACL injuries. The PEP significantly ($p<0.05$) increased electromyography (EMG) activity for muscles in both the dominant and non-dominant legs prior to and after the landing of the vertical jump component of the drop rebound jump in relation to control measures. These results indicate the effectiveness of the PEP as a warmup routine for high risk sports.

KEY WORDS: warmup, knee, ligament, prevention, electromyography.

INTRODUCTION: ACL injuries within multi directional stop start sports such as basketball and soccer are prevalent with the incidence of injury being 0.17 to 0.49 per 1000 exposures (Prodromos, Han, Rogowski, Joyce, & Shi, 2007). Up to 95% of all ACL injuries within a sporting context occur without any direct contact to the knee by an external source (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007). Muscular recruitment plays a role in protecting the ACL during constant acceleration and deceleration activities (Hewett, Ford, Hoogenboom, & Myer, 2010). Athletes who are able to symmetrically recruit numerous muscle groups such as those that make up the posterior chain during sport performance can dissipate ground reaction forces away from the knee and ACL preventing injury (Hewett & al., 2010). Research has also shown that the periods of time just before and immediately after foot touch down are when the ACL is at its most vulnerable, therefore correct muscular recruitment at these times is essential to avoiding injury (Dai, Herman, Liu, Garrett, & Yu, 2012a).

The PEP was designed as a warmup routine to prevent ACL injuries. Studies have shown that the PEP can reduce ACL injuries in terms of their total number over a prolonged period of time; however, despite the fact that the PEP is a warmup by design there is a lack of research on its immediate effects on lower extremity biomechanics (Lim et al., 2009; Dai et al., 2012). Also, those studies which have measured the PEP's ability to alter muscular activity have only done so in a chronic setting (Lim et al., 2009). This study therefore aims to test the acute effects the PEP has on muscular activity in relation to noncontact ACL injury risk factors during a task which mimics the movement patterns seen in ACL injuries, specifically, within the time frames when the ACL has been labelled as "at risk" of injury.

METHODS: 8 male athletes (height 1.89 ± 0.07 m, mass 91.31 ± 11.14 kg) between the ages of 19 and 25 (average 22 ± 1.69 years) were recruited to take part in this study. Each of the participants in this investigation trained for and competed in what would be labelled by previous research as a "high risk" sport (basketball 6, soccer 1 & rugby union 1) in terms of ACL injury (Dai et al., 2012a; Dai, Herman, Liu, Garrett, & Yu, 2012b).

The testing protocol had 6 stages:

1. Control Warmup - Participants warmed up for 10 minutes with some light cycling on a stationary bike which marked the start of the control protocol. Following the cycling static stretches for the quadriceps, hamstrings and glutes were then performed. EMG electrodes were then placed onto the corresponding muscles (rectus femoris, biceps femoris and gluteus maximus of each leg) before beginning maximum voluntary contraction (MVC) testing.
2. Control MVC Testing – In order to gain a reading of maximal muscular activity MVC testing was performed. A knee flexion/extension bench was attached via a chain to a force

platform and the participants were instructed to generate as much force as possible in order to gain a maximal EMG reading for the rectus femoris and biceps femoris. A resisted glute bridge was used to gain a reading of maximal gluteus maximus EMG signal. Each MVC lasted for 5 seconds with a rest period of 5 minutes in between each pair of MVC. Subjects performed 3 MVC for each leg; EMG was only gathered for the second MVC of each leg.

3. Control Drop Jump Testing – In order to measure muscle activity during a task which mimicked the rapid deceleration to acceleration patterns seen during ACL injuries drop jumps were performed. Participants dropped off of a 30cm box onto the force plate and immediately performed a maximal vertical jump and landing (Padua et al., 2009). A total of 7 successful drop jumps were required.
4. PEP Warmup – Participants then performed the PEP warmup routine commencing the start of the experimental protocol.
5. Experimental MVC Testing – The same MVC testing procedure as earlier was followed.
6. Experimental Drop Jump Testing - The same drop jump testing procedure as earlier was followed.

Kinetic data was analysed using BioWare (BioWare® version 5.x, Kistler Instruments Ltd, Hampshire, UK). Initial contact was labelled as the point in time when ground reaction force immediately rose above 10 N (Cowley, Ford, Myer, Kernozek, & Hewett, 2006). Similarly, the event of take-off was registered at the immediate time ground reaction force fell below 10 N (Cowley & al., 2006). Ground reaction forces were normalized to body weight (N) (Cowley et al., 2006).

EMG data was analysed using Delsys EMG works analyses software version 4.1.7. EMG data was averaged over the middle portion of each 5 second MVC (Nagano, Ida, Akai, & Fukubayashi, 2006). This was used for normalization of the muscle activity during the drop rebound jumps. Average EMG was also taken for the 50 ms period prior to and after vertical jump landing (Dai et al., 2012). Raw EMG signals were rectified and band pass filtered at 20 Hz and 450 Hz. A Butterworth second class fourth order low pass filter at 10 Hz was then applied.

All statistical analysis was conducted using SPSS (IBM SPSS Statistics version 21, IBM Corporation, NY, USA). Initially the data was checked for normality via the Kolmogorov-Smirnov & Shapiro-Wilk tests. Paired samples t tests were used to compare the mean scores between the control protocol and experimental protocol results. Cohen’s d was calculated as a measure of effect size between each pair of means.

RESULTS: Table 1, below, depicts the average percentage of EMG activity in relation to the maximal readings gathered from MVC testing for each muscle during each time period prior to and after performing the PEP.

Table 1

Variable	Control (%mV)	Experiment (%mV)	P Value	Effect Size (d)
Pre VJ D RF	23.7 (±15.18)	45.74 (±35.29)	0.02	1.06
Pre VJ ND RF	25.69 (±18.88)	50.34 (±26.86)	0.002	1.77
Pre VJ D BF	32.71 (±27.28)	66.59 (±62.39)	0.03	0.96
Pre VJ ND BF	33.4 (±26.38)	52.26 (±27.03)	<0.001	2.4
Pre VJ D GM	57.15 (±37.32)	101.37 (±65.37)	0.005	1.41
Pre VJ ND GM	65.8 (±39.44)	110.07 (±35.94)	<0.001	2.49
Post VJ D RF	50.66 (±30.35)	67.28 (±42.26)	0.012	1.18
Post VJ ND RF	50.5 (±22.83)	64.91 (±29.61)	0.047	0.85
Post VJ D BF	69.4 (±54.54)	97.68 (±76.86)	0.013	1.17
Post VJ ND BF	59.16 (±30.88)	65.15 (±23.49)	0.298	0.4
Post VJ D GM	122.74 (±74.48)	154.34 (±78.47)	0.007	1.34
Post VJ ND GM	133.25 (±41.25)	143.54 (±40.14)	0.306	0.39

RF: Rectus Femoris BF: Biceps Femoris GM: Gluteus Maximus D: Dominant
ND: Non-dominant R: Rebound Landing VJ: Vertical Jump Landing mV: millivolts

Every muscle's EMG activity significantly increased for the dominant and non-dominant legs during both the pre and post vertical jump landing phases except for the non-dominant biceps femoris and gluteus maximus. Each statistically significant ($p<0.05$) pairing also had a large effect size. On the other hand, each pairing that was not statistically significant ($p>0.05$) had a relatively low effect size.

DISCUSSION: From Table 1 we can see that in each of the pre-landing phase's rectus femoris activity significantly increased with substantial effect size. Enhanced quadriceps activity in anticipation of landing has been shown to decrease ACL strain (Hashemi et al., 2010). This reduction in ACL strain and therefore injury risk was attributed to the quadriceps preventing tibial translation relative to the femur (Shin, Chaudhari, & Andriacch, 2011). Taking this into consideration along with the level of significance and effect size seen in this study results suggest that the PEP programme is able to reduce the risk of ACL injury in an acute setting. Significantly greater quadriceps activity during the pre-landing phase will reduce tibial translation relative to the femur contributing to decreased ACL strain and therefore lower risk of injury.

In both the pre and post vertical jump landing phases all muscular activity (with the exception of the non-dominant biceps femoris and gluteus maximus in the post vertical jump landing period) was significantly higher after performing the PEP. This enhancement of muscular activity will reduce the risk of ACL injury in relation to ligament dominance. It has been stated that ineffective recruitment of muscles during landing forces the ACL to passively absorb large amounts of ground reaction force in the absence of muscle activation (Myer, Ford, & Hewett, 2004). Specific recruitment of the kinetic posterior chain has been shown to further decrease the risk of ACL injury (Myer et al., 2004). Both the biceps femoris and gluteus maximus are contained within the kinetic posterior chain. The enhanced activity of these muscles as a result of the PEP served to reduce ligament dominance and therefore risk of ACL injury.

Continuing to focus on the increased EMG activity of the muscles that make up the kinetic posterior chain it is clear the PEP was able to reduce quadriceps dominance. Like ligament dominance quadriceps dominance relies heavily on the athlete's ability to fully recruit the kinetic posterior chain (Myer et al., 2004). The utilisation of numerous muscle groups with multiple tendinous insertions allows for reaction forces to be effectively dissipated and not focused on the knee joint as is the case with quadriceps dominance (Hewett et al., 2010). Enhanced kinetic posterior chain recruitment reduced anterior shear stress to the tibia, which has been argued to be the primary contributor to ACL loading (Markolf et al., 1995) leading to a decrease in ACL injury risk (Hewett et al., 2010). Similarly, anterior shear stress and therefore ACL injury risk may have decreased in this study by way of a reduction of quadriceps dominance as a result of the PEP routine enhancing bicep femoris and gluteus maximus EMG activity.

Specifically focusing on the improvement in biceps femoris EMG activity following the completion of the PEP it can be further argued that the PEP has the ability to reduce anterior shear force and therefore ACL strain. Enhanced recruitment of the hamstrings increases knee flexion angle avoiding an extended knee upon landing which has been shown to be one of the main causes of ACL injuries (Donnelly et al., 2012). Large amounts of anterior shear force have been seen when the knee is in an extended position during landing, however, hamstring activity brings about the desired flexed position so that the hamstrings can align to resist anterior drawer (Hewett et al., 2010). Cocontraction of the hamstrings with the quadriceps has also been shown to decrease ACL strain by preventing tibial displacement relative to the femur (Hewett et al., 2010). With the enhanced hamstring EMG activity coupled with the increased quadriceps recruitment seen in this study which corresponds to the studies just mentioned the PEP was therefore able to reduce anterior shear force.

CONCLUSION: This study found that in an acute setting the PEP routine was able to significantly enhance with large effect sizes the muscular activity in athletes' dominant and non-dominant legs during a sudden deceleration transitioning into high acceleration manoeuvre which mimicked the movement patterns seen in ACL injuries. Specific improvements in EMG activity during pre-landing phases and recruitment of kinetic posterior chain muscles highlights the ability of the PEP to positively address biomechanical risk factors and acutely reduce the risk of ACL injury. In conclusion the PEP is a highly viable warmup routine for sports involving rapid changes of direction and exposure to large ground reaction forces where ACL injuries are common.

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