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Exploring individual adaptations to an anterior cruciate ligament injury prevention programme

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ABSTRACT

Background: Individual responses to anterior cruciate ligament injury prevention programmes (ACL IPPs) have received little attention. This study examined the effects of an ACL IPP on neuromuscular control and lower limb biomechanics during landing at the group and individual levels.
Methods: Sixteen female athletes were randomly allocated to training ($n = 8$) or control ($n = 8$) groups. Electromyography, and three-dimensional kinematic and kinetic data were collected during landing at two testing sessions. Repeated measures ANOVA and effect sizes (Cohen's d) examined the effect of the IPP at the group and individual levels. A sub-group analysis comparing the effect of the IPP on 'high-' (i.e. large peak knee abduction moment at baseline) versus 'low-risk' individuals was also conducted.
Results: At the group level; the IPP increased activation of the medial hamstrings prior to landing ($p < 0.001$; $d = 0.264$) and the medial gastrocnemius at landing ($p < 0.001$; $d = 0.426$), and increased hip external rotation early after initial contact ($p < 0.001$; $d = 0.476$). Variable adaptations were seen across individuals within the training group for all variables ($p < 0.001$). The IPP had a large effect in reducing frontal plane knee moments for 'high-risk' individuals ($d > 0.91$), however these results did not reach statistical significance ($p > 0.05$).
Conclusions: The IPP induced adaptations during landing, however, individual data revealed dissimilar responses to the programme. Individuals displaying a pre-existing high-risk strategy may incur greater benefits from IPPs, yet only if the programme targets the relevant high-risk strategy.

1. Introduction

Anterior cruciate ligament (ACL) injuries lead to a range of short- and long-term consequences, with the most concerning being the elevated risk of developing early onset osteoarthritis subsequent to injury [1,2]. Primary prevention is an effective means for avoiding these future disabilities [3]. Subsequently, injury prevention programmes (IPPs) aimed at reducing the incidence of ACL injuries or modifying neuromuscular and biomechanical risk factors are prominent throughout the literature.

The success of ACL IPPs is generally defined by a reduction in the total number or rate of ACL injuries. Success of a programme may also be inferred by a change in biomechanical or neuromuscular factors associated with ACL loading or injury risk. Regardless of the outcome of interest, an improvement in the training group (in isolation or relative to a control group) is often deemed as successful, with little attention paid to individual responses. Despite the apparent success of IPPs in recent times, ACL injury rates

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have remained relatively unchanged [4,5]. A focus on group results limits our understanding of how different individuals respond to training, and this may be a factor that restricts our understanding of the mechanisms that underpin failure or success of ACL IPPs. Certain individuals have been shown to exhibit detrimental responses to training, even when an overall improvement has been observed at the group level [6]. It may therefore be erroneous to expect that everyone will gain similar benefits from an identical training stimulus. Despite this, individual responses to ACL IPPs have received little attention.

Certain studies have considered the individual responses to ACL IPPs [6–8]. Where this has been examined, non-uniform adaptations have been observed [6–8]. Cowling et al. [7] found individuals displayed non-uniform adaptations in quadriceps and hamstrings muscle activation strategies during a unilateral catch-and-land task, despite completing identical training programmes. No differences were found from pre- to post-training when examining the group, highlighting the potential of individual responses to be masked when focusing on data at the group level. Pollard et al. [6] concluded an in-season IPP had a beneficial effect on frontal and transverse plane hip motion when performing a drop jump-landing task. Upon examination of individual data, some athletes were found to have greater improvements in the frontal versus transverse plane, and vice versa [6]. It was suggested that athletes exhibited greater changes in the plane they demonstrated a pre-existing high-risk pattern [6]. However, certain athletes also exhibited detrimental adaptations following training [6]. Further, Dempsey et al. [8] found certain athletes exhibited large favourable responses in torso rotation during a side-step cutting manoeuvre following training, while others did not. The authors also hypothesised that these athletes may have displayed a more high-risk technique at baseline, and hence obtained a greater benefit from training. The level of ACL injury risk prior to commencing an IPP is a potential modulating factor in the magnitude of response to training [9]. Myer et al. [9] saw a greater decrease in knee abduction moments during a bilateral drop vertical jump task in 'high-' (knee abduction moment > 22.5 Nm during a drop vertical jump) versus 'low-risk' athletes.

Of the studies which have examined individual changes following an ACL IPP, there appears to be a consensus that not all athletes respond in a similar manner. While a large number of studies have assessed biomechanical and neuromuscular adaptations following an IPP, very few have specifically focused on the variable responses of individuals. Failure to examine these individual responses may impact on our understanding of what constitutes effective ACL injury prevention practice. While an IPP may be effective at the group level, not all individuals may receive the perceived benefits and thus may still be at-risk of ACL injury. A greater understanding of how individuals respond to identical training can allow for better development of ACL IPPs that provide a benefit to all involved.

The purpose of this study was to examine the effects of an ACL IPP on neuromuscular control and lower limb biomechanics during a high-risk landing task at the group and individual levels. Specifically, this study aimed to: (i) investigate the effects of an ACL IPP at the group level by comparing the overall responses between a control and training group; (ii) investigate the effects of an ACL IPP at the individual level by examining the individual responses of athletes within a training group; and (iii) determine whether individuals' deemed as 'high-risk' at baseline received a greater prophylactic benefit from the ACL IPP. It was hypothesised that the training group would benefit from the IPP as indicated by improvements in risk factors associated with ACL injury; however, variable responses to the programme would be observed across individuals within the training group. In addition, individuals deemed as 'high-risk' for ACL injury would receive a greater prophylactic benefit from the training.

2. Methods

2.1. Participants

Project approval was given by the University's Human Research Ethics Advisory Group. All participants were informed of the purpose of the research and possible hazards of participation, and were required to give informed consent prior to testing. Sixteen sub-elite female netball players (mean ± standard deviation age = 22.7 ± 2.7 years; height = 171.8 ± 7.4 cm; mass = 68.6 ± 8.1 kg) volunteered to participate in the study. Players were free from current injury, had not suffered an injury to the lower back or lower limb in the past six months, and had no history of lower back or lower limb surgery. Participants were also required to have had no previous exposure to an ACL IPP as part of their training history. A block randomisation approach was used to allocate participants to a control ($n = 8$; age = 23.4 ± 2.7 years; height = 171.6 ± 7.6 cm; mass = 69.8 ± 11.0 kg) or training ($n = 8$; age = 22.0 ± 2.5 years; height = 172.0 ± 7.6 cm; mass = 67.9 ± 4.8 kg) group. No statistically significant differences ($p > 0.05$) were present for age, height and mass, netball experience, and training frequency between groups.

2.2. Experimental protocol

Participants attended two identical testing sessions separated by a six-week period. A netball-specific leap landing was chosen as the experimental task for this study (see Figure 1). Additional details relating to this landing task are described in previous work [10]. The landing was initiated by breaking and accelerating from a static defender, followed by a run-up and leap landing while catching a pass. Trials were excluded if the pass was not between chest and head height, was not within half a metre of the participant, or if the participant failed to catch the pass. All landing trials were completed on the participant's designated 'landing limb,' determined by asking players to trial landing on each limb, and selecting which was preferred. Participants were given as many practice trials as necessary to become familiar with the task, and 20 successful landings were recorded thereafter. To minimise fatigue, participants were given 60–90 s of rest between trials. A successful trial was characterised by: (i) performing the landing on the designated limb with the entire foot landing within the borders of the force plate; (ii) successfully catching the pass; and (iii) coming to a complete stop within one step after landing. Participants were instructed to perform the landing

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