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Changes in muscle activation following balance and technique training and a season of Australian football

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ABSTRACT

Objectives: Determine if balance and technique training implemented adjunct to 1001 male Australian football players' training influenced the activation/strength of the muscles crossing the knee during pre-planned and unplanned sidestepping.
Design: Randomized Control Trial.
Methods: Each Australian football player participated in either 28 weeks of balance and technique training or 'sham' training. Twenty-eight Australian football players (balance and technique training, $n = 12$; 'sham' training, $n = 16$) completed biomechanical testing pre-to-post training. Peak knee moments and directed co-contraction ratios in three degrees of freedom, as well as total muscle activation were calculated during pre-planned and unplanned sidestepping.
Results: No significant differences in muscle activation/strength were observed between the 'sham' training and balance and technique training groups. Following a season of Australian football, knee extensor ($p = 0.023$) and semimembranosus ($p = 0.006$) muscle activation increased during both pre-planned sidestepping and unplanned sidestepping. Following a season of Australian football, total muscle activation was 30% lower and peak valgus knee moments 80% greater ($p = 0.022$) during unplanned sidestepping when compared with pre-planned sidestepping.
Conclusions: When implemented in a community level training environment, balance and technique training was not effective in changing the activation of the muscles crossing the knee during sidestepping. Following a season of Australian football, players are better able to support both frontal and sagittal plane knee moments. When compared to pre-planned sidestepping, Australian football players may be at increased risk of anterior cruciate ligament injury during unplanned sidestepping in the latter half of an Australian football season.

1. Introduction

In Australia, 52/100,000 people per year rupture their anterior cruciate ligament (ACL),[1] representing the highest injury rates per capita world-wide.[2] Two general biomechanical approaches can be used to reduce an athlete's risk of ACL injury in sport. First, decrease the external forces applied to the knee by changing their technique during a sporting task.[2–4] Second, increase the strength and/or activation of the muscles with moment arms capable of supporting the knee when external loading is elevated.[2,5,6] Specifically, increasing a muscles ability to support the knee from externally applied flexion and/or anterior shear forces are thought to be appropriate to reduce an athlete's risk of ACL injury in sport,[2,7,8] as these are the loading patterns shown to elevate ACL strain *in vivo*.[9] With no single muscle crossing the knee is capable providing support in all three degrees of freedom simultaneously; therefore different muscle activation strategies can be used to support the knee and ACL during dynamic sporting tasks. In general, muscle activation strategies capable of countering externally applied flexion, valgus, internal rotation moments and/or shear forces include generalized hamstring/quadriceps co-contraction, superimposed with the elevated activation of muscles with flexion, and/or medial moment arms.[2]

Incorporating knee joint kinematic and kinetic data presented previously[10] with measures of lower limb muscle activation, which is presented in this manuscript, there were three purposes of

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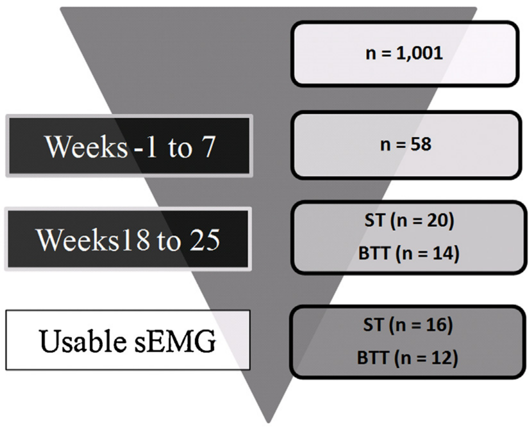

	Testing Session 1 (wks -1 to 7)		*Testing Session 2* (wks 18 to 25)	
	ST (n = 16)	BTT (n = 12)	ST (n = 16)	BTT (n = 12)
Age (yrs)	21.2 ± 2.7	21.2 ± 3.7	21.9 ± 2.8	21.5 ± 3.1
Height (m)	1.84 ± 0.08	1.86 ± 0.09	1.84 ± 0.08	1.86 ± 0.09
Mass (kg)	81.6 ± 9.9	82.5 ± 10.2	81.4 ± 9.9	82.2 ± 10.6

Fig. 1. Experimental data flow of training intervention and biomechanical testing sessions 1 and 2. BTT and ST number were only reported in testing session two as the biomechanists conducting the data collections were blinded to the training intervention codes of each participant until the statistics phase of the analysis. Mean ± standard deviation age, body mass and height were reported for participants who completed both testing sessions 1 and 2.

this investigation: (1) determine if balance and technique training (BTT) implemented in a 'real-world' training environment, adjunct to normal Australian football (AF) training influenced the activation/strength of the muscles crossing the knee during pre-planned (PpSS) and unplanned (UnSS) sidestepping. (2) Determine if muscle activation/strength changes over a season of AF and (3) determine if changes in muscle activation were proportional to changes in peak knee moments.[10] The term 'real-world' training is defined as an intervention conducted in a field-based, community level training environment, with instruction given by a trainer/coach blinded to the intended aims and outcome measures of the training intervention.

2. Methods

These methods are a condensed version of those described previously.[10,11] Additionally, interested readers can obtain a complete copy of the BTT and the 'sham' training (ST) intervention training protocols through the corresponding author. This study was approved by the Human Research Ethics Committees at The University of Western Australia (UWA) and the University of Ballarat.

All AF players provided their informed, written consent prior to participating in their respective training interventions and when applicable, biomechanical testing. As part of a larger group-clustered randomized controlled trial, eight Western Australian Amateur Football League clubs (n = 1001 males) volunteered to participate in either 28 weeks of BTT or ST intervention adjunct to their 2007 or 2008 regular season training.

An independent research assistant was contracted to recruit participants by phone for biomechanical testing. From an alphabetical list of the 1001 eligible AF players, 58 volunteered for biomechanical testing one week prior to (week −1) through the first seven weeks (week 7) of each clubs 8 week pre-season. Of these 58, 34 AF players were available for post testing in weeks 18–25 of the 28-week training intervention, which corresponded to the beginning of the BTT and ST maintenance phases. Both knee loading and usable surface electromyography (sEMG) data were obtained from 28 (48%) participants (BTT, n = 12; ST, n = 16) (Fig. 1). Only one of the 24 AF players that did not return for follow-up biomechanical testing was able to be contacted by phone. The reason this individual did not attend follow-up biomechanical testing was due to injury. As we could not contact the remaining 23 AF players, data associated with why they did not attend the second biomechanical testing session is not available.

Each club trained two times per week and played a match once a week over the 28 week training interventions. Training interventions were conducted as a pre-training warm-up for 20 min, twice a week for the first 18 weeks, and then once a week until the end of the 28 week training intervention. Training sessions were run by two instructors blinded to (1) the aim of the training programs they were overseeing, and (2) the outcome measures analyzed during biomechanical testing. Instructors also recorded player attendance and participation following each training session.

Balance training included single-leg, wobble board, stability disk and Swiss stability ball balance tasks. Each balance exercise became progressively more difficult from week 1 to week 18 with the last 10 weeks of training designed as a maintenance phase. Again, all follow up biomechanical testing started in week 18. During each training session, when appropriate, AF players were verbally instructed to keep their stance foot close to midline, maintain a controlled vertical trunk posture and increase knee flexion during the stance phase of both sidestepping and landing tasks.

The ST group served as the experimental control group. The goal of the ST intervention was to improve each athlete's acceleration during straight-line running tasks, which to our knowledge has not been shown to influence an athlete's peak joint loading or ACL injury rates. Other differences between the ST and BTT groups were that the ST group did not receive technique feedback from their instructors and did not participate in any balance type exercises during training. The difficulty of the exercises used in the ST intervention progressed with difficulty in a similar fashion to the BTT protocol.

Each biomechanical testing session started with an assessment of each AF players' lower limb strength. Assessments included maximum effort isometric hip abduction/adduction torque, isokinetic eccentric knee flexion/extension torque, maximum countermovement jump height as well as a single-leg whole-body balance assessment. See supplementary materials B for a full description of these procedures.

Each AF player completed a random series of pre-planned and unplanned straight run, crossover and sidestep sporting tasks with their self-selected preferred leg.[10,12] Participants completed three successful trials of each sporting task before testing was complete. Three-dimensional full-body kinematics were recorded.[3,10] These data with a custom lower body kinematic model in Bodybuilder (Vicon Peak, Oxford Metrics Ltd., UK) were used to calculate knee flexion angles and peak knee moments *via* inverse dynamics during weight acceptance (WA). A full description of the kinematic and kinetic modeling approaches used to calculate relevant knee kinematic and kinetic variables have been described previously.[10]

During the running and sidestepping trials, sEMG data was collected using a 16-channel telemetry system (TeleMyo 2400 G2, Noraxon, Scottsdale, Arizona) at 1500 Hz with a 16 bit A/D card. Input impedance was >100 MΩ and CMR was >100 dB. Using bipolar 30 mm disposable surface electrodes (Cleartrace™ Ag/AgCl, ConMed, Utica, NY), with an inter-electrode distance of 30 mm, eight pairs of electrodes were placed over the muscle bellies of eight muscles crossing the knee as per recommendations from Delagi et al.[13] (tensor fasciae latae (TFL) semimembranosus (SM), biceps femoris (BF), vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF), medial gastrocnemius (MG) and lateral gastrocnemius (LG)).

Using customized software in MatLab (Matlab 7.8, The Math Works, Inc., Natick, MA, USA), the sEMG data was processed by first removing direct current offsets, then band-pass filtered with a