THE EFFECTIVENESS OF NEUROMUSCULAR TRAINING WITH AUGMENTED FEEDBACK ON ACL INJURY PREVENTION

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This study determined whether the neuromuscular training program with augmented feedback was effective in decreasing the injury rate of ACL during landing. Seventeen male and 16 female college basketball or velleyball players were randomly divided into training (4-weeks duration), or control group (no training). Kinematic data collected by 8 infrared cameras of Motion Analysis System (200 Hz) were synchronized with kinetic data from 4 Kistler force plates (9281CA) (1000 Hz). The injury prevention training only signifcantly reduced ground reaction forces in the training group ($p < 0.05$) with no statistical difference in knee flexion angle, varus–valgus moment and internal–external rotation moment. There was a likely beneficial decrease in valgus moment and internal rotation moment in the male training group and possibly harmful increase internal rotation moment in female training group. There was possibly-to-likely harm in GRF, knee flexion angle and valgus moment in the control group. The neuromuscular training with augmented feedback reduced ground reaction forces in college basketball and volleyball players, and thus may reduce the risk of ACL injury in landing.

KEYWORDS: ACL, injury prevention, augmented feedback, neuromuscular training

INTRODUCTION: Anterior cruciate ligament (ACL) injury is a common injury in sports. After injury, it often seriously affects the patient's exercise performance and quality of life. The majority of ACL injuries occurs without physical contact. The noncontact nature of the majority of ACL injuries suggests that many ACL injuries may be preventable using soft landing techniques with active flexion motions of the lower extremity (Liu et al. 2014). A variety of neuromuscular training programs have been developed in an attempt to reduce the risk of ACL injuries in sports, including injury education, augmented and sensory feedback training, strength training, plyometric training, and balance training. The effects of ACL injury prevention programs on ACL injury rates are inconsistent, which could be attributed to lack of understanding of risk factors for ACL injury and low compliance (Dai et al. 2014). The purpose of this study was to design a new ACL injury prevention programs based on risk factors for ACL injury to improve low compliance. The training program is focused on landing technique, and can be done as short at 20 minutes in place of a typical warm-up.

METHODS: Inclusion criteria for selecting subjects are (1) knee flexion angle is less than 35° when landing; (2) college basketball or volleyball players; (3) no history of lower extremity disorders. 20 male and 20 female were recruited. Subjects were randomly divided into training group and control group by lottery. The training group performed the ACL injury prevention program with a 4-week duration, whereas the control group did not. Finally, 17 people in the training group and 16 in the control group completed all the tests, as some subjects withdrew from the experiment.

The training program for preventing ACL injury contained 4 parts: (1) Worm up activities, core strength and proprioception exercises; (2) strength training on hip and knee; (3) plyometric landing exercise with feedback; (4) Relaxing activities such as static stretch. Instant augmented feedbacks were provided when landing error appeared. Operational Definitions for Individual Landing error included: (1) one foot lands before the other foot; (2) the foot lands heel to toe or with a flat foot at initial contact; (3) the feet are positioned greater than or less than shoulder width at initial contact; (4)the center of knee is medial to the midfoot at initial contact; (5) the knee is flexed less than 30° at initial contact; (6) the midline of the trunk is flexed to the left or the right side of the body at initial contact(Padua et al. 2015).

Table 1: Information of subjects

Group	Gender	N	Age (Y)	Height（cm）	Weight（kg）
Training	male	9	21.7±1.3	190.0±9.1	82.5±17.1
	female	8	21.2±1.9	177.7±4.2	72.3±4.7
Control	male	8	21.3±1.5	190.1±2.6	82.3±10.7
	female	8	22.3±0.9	177.3±7.6	66.6±8.2

Table 2: Training Program for ACL injury Prevention

Exercise	Movements	Sets/Time
Warm up		
	Glute Bridge - Marching	1 × 6 reps
	External Hip Rotation - Side lying	1 × 6 reps
	Leg Overs	1 × 6 reps
	Knee Hug - Moving	1 × 6 reps
	Reverse Lunge - with Twist	1 × 6 reps
	Knee Hug to Forward Lunge - Elbow to Instep	1 × 6 reps
	Drop Lunge	1 × 6 reps
	Lateral Squat - Low	1 × 6 reps
	Inverted Hamstring - Moving Forward	1 × 6 reps
	Heel to Butt - Moving Forward with Arm Reach	1 × 6 reps
Strengthening		
	Walking lunges	2 × 30 s
	Russian hamstring	2 × 30 s
	Single-toe raises	2 × 30 s
	Deadlift	2 × 30 s
Plyometrics		
	Lateral hops	3 × 6 reps
	Forward hops	3 × 6 reps
	Single-legged jumps	3 × 6 reps
	Vertical jumps	3 × 6 reps
	Scissors jumps	3 × 6 reps
Stretching		
	Calf stretch	2 × 30 s
	Quadriceps stretch	2 × 30 s
	Hamstring stretch	2 × 30 s
	Inner thigh stretch	2 × 30 s
	Hip flexor stretch	2 × 30 s

Each subject was asked to perform three successful trials of a stop-jump task that consisted of an approach run up to five steps followed by a two-footed landing, and two-footed vertical take-off for maximum height. Passive reflective markers were placed on the critical body landmarks. Kinematic data were collected by 8 infrared camera of Motion Analysis System (200 Hz). Four Kistler force plates (9281CA) were collected at frequency of 1000 Hz. Kinetic data and kinetic data were synchronized. GRFs were standardise by body weight (BW) and moments were standardised by body weight * body height (BH.BW).

Magnitude-based inferences were used to assess clinical worth of positive outcomes reported in studies. To make Magnitude-Based Inferences about true values of the effect of the training, the uncertainty in the effect was expressed as 90% confidence limits and as likelihoods that the true value of the effect represents substantial change (harm or benefit) (Hopkins, 2002). An effect was deemed unclear if its confidence interval overlapped the thresholds for substantiveness; that is, if the effect could be substantially positive and negative, or beneficial and harmful. The smallest standardized change was assumed 0.20 (Cohen, 1988).

RESULTS: The injury prevention training significantly reduced vertical and posterior ground reaction forces in training group ($p < .05$) with no statistical difference in knee flexion angle, varus–valgus moment and internal–external rotation moment. However, magnitude-based inferential statistics revealed likely beneficial decrease in valgus moment and internal rotation moment in male training group and possibly harmful increase internal rotation moment in female training group. There were no statistical differences in all indicators in the control group. However, magnitude-based inferential statistics revealed possibly-to-likely harm in GRF, knee flexion angle and valgus moment in control group.

Table 2: Biomechanics parameters of lower limb before and after training in stop-jump task

Group	Gender	Parameters (at 1st GRF peak)	Pre Mean±SD	Post Mean±SD	Difference; ± 90%CL	Qualitative inference
Training	Male(n=9)	Posterior GRF (BW)	0.88±0.35	0.53±0.25	-0.34; ±0.27	very likely beneficial
		Vertical GRF (BW)	1.62±0.41	1.09±0.59	-0.53; ±0.26	very likely beneficial
		Knee flexion (°)	33.49±9.64	36.78±10.15	3.29; ±9.33	Unclear
		Knee VV moment (BH.BW)	-0.1±0.19	-0.01±0.16	0.09; ±0.12	likely beneficial
		Knee rotation moment (BH.BW)	-0.02±0.03	0.01±0.03	0.03; ±0.03	likely beneficial
	Female(n=8)	Posterior GRF (BW)	0.8±0.22	0.49±0.23	-0.31; ±0.08	most likely beneficial
		Vertical GRF (BW)	1.89±0.71	0.84±0.37	-1.05; ±0.43	most likely beneficial
		Knee flexion (°)	27.97±8.01	28.29±7.48	0.32; ±10.83	Unclear
		Knee VV moment (BH.BW)	-0.09±0.07	-0.17±0.46	-0.08; ±0.35	Unclear
		Knee rotation moment (BH.BW)	0.01±0.02	0±0.05	-0.01; ±0.03	possibly harmful,
Control	Male(n=8)	Posterior GRF (BW)	0.53±0.29	0.64±0.21	0.1; ±0.21	possibly harmful
		Vertical GRF (BW)	1.09±0.35	1.3±0.47	0.21; ±0.47	possibly harmful,
		Knee flexion (°)	31.96±10.32	25.73±8	-6.23; ±5.62	likely harmful
		Knee VV moment (BH.BW)	0.06±0.18	-0.08±0.14	-0.15; ±0.15	likely harmful
		Knee rotation moment (BH.BW)	-0.02±0.03	0±0.05	0.02; ±0.03	Unclear
	Female(n=8)	Posterior GRF (BW)	0.52±0.09	0.63±0.23	0.11; ±0.12	likely harmful
		Vertical GRF (BW)	1.16±0.51	1.36±0.85	0.2; ±0.64	possibly harmful
		Knee flexion (°)	38.53±19.65	26.32±10.78	-12.21; ±17.19	likely harmful
		Knee VV moment (BH.BW)	-0.09±0.17	-0.09±0.1	0.01; ±0.13	Unclear
		Knee rotation moment (BH.BW)	0.00±0.04	0.01±0.02	0.01; ±0.04	Unclear

VV moment: positive values mean varus and negative values mean valgus.
Rotation moment: positive values mean external rotation and negative values mean internal rotation.

DISCUSSION: The ACL is a primary restraint to anterior translation of the tibia relative to the femur. The magnitude of anterior shear force applied on the tibia and its effect on ACL loading are largely affected by the posterior ground reaction force and knee flexion angle during a movement. The posterior GRF on the foot during a movement creates a flexion moment at the knee that needs to be balanced by an extension moment at the knee. While generating knee moments, the quadriceps applies an anterior shear force at the proximal end of the tibia that is a primary cause of anterior tibia translation and ACL loading mechanism (Dai et al. 2014). The results of this study show that the training program for injury prevention effectively reduce the ground reaction force and further reduced anterior shear force of ACL.

Taylor et al. showed that knee flexion angle and ACL length were negatively correlated and the peak ACL length actually occurred prior to landing when the knee flexion angle was minimal. ACL loading decreased when knee flexion angles increased. Injury prevention training did not increase the knee flexion angle when landing. However, magnitude-based inferential statistics revealed likely harmful decrease in knee flexion in control group. This may reveal that landing techniques of college basketball and volleyball players become worse as the season progresses and injury prevention training may prevent this bad trend.
Shin et al. has shown that combined valgus and internal rotation moments increase strain in the ACL more than either alone. This predicted high ACL strain and contact force location in this study suggest that combined valgus and tibial internal rotational moments during landing motion are relevant to the rupture of the ACL (Shin et al., 2011). In this study, injury prevention training made likely beneficial decrease in valgus and internal rotation moment in male players and yet possibly harmful increase internal rotation moment in female players. However, none of these findings were statistically different at $p < 0.5$.
The augmented feedback for landing error gave participants opportunities to couple their task intrinsic feedback, which is the feedback from sensory receptors in muscles, tendons, and joints, with the targeted movement pattern. The participants gradually developed the memory of matching the task intrinsic feedback and the targeted movement pattern. This memory later ‘‘guided’’ the participants to achieve the targeted movement pattern. However, excessive frequent augmented feedback can hinder motor learning. This overuse of augment feedback might prevent the participants from using their own intrinsic feedback and from developing their own error detection capability. Therefore, the augment feedbacks were sporadically provided in this study.
A significant limitation of this study was that the training effects were evaluated only in well-controlled laboratory tests instead of actual practice or competitions. The effects of training on movement patterns in actual practice and competitions are still unknown. Another limitation of this study is that instant feedback for bad landing techniques require assistance from professional personnel. These requirements for professional personnel may not be realistic for many athletes, especially for recreational athletes.

CONCLUSION: The neuromuscular training with augmented feedback reduced ground reaction forces in college basketball and volleyball players, and thus reduced the risk of ACL injury in landing.

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