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Original Research

Comparison of Kinematic Risk Patterns Associated with ACL Injury During an Unanticipated Cutting Maneuver in Athletes with and without Non-Specific Chronic Low Back Pain

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ABSTRACT

Athletes with nonspecific chronic low back pain (CLBP) may have different kinematic patterns during cutting maneuver compared with healthy individuals. To investigate the kinematic risk patterns of anterior cruciate ligament injury (ACL) during an unexpected cutting maneuver in athletes with non-specific CLBP and compare it with those without nonspecific CLBP athletes. Twenty female athletes (10 with nonspecific CLBP and 10 without nonspecific CLBP) participated in this study. All participants engaged in sports whose common movements included cutting maneuvers. Participants performed an unanticipated cutting maneuver based on the direction in which the visual stimulus was shown by the examiner. A three-dimensional motion analysis system was used to collect the data on the knee and trunk flexion, knee valgus and tibia rotation on the femur at initial contact and peak value. Kinematic data were processed by Nexus software. An independent t-test was used in SPSS software at a significance level of 5% to compare variables between two groups. The results showed that peak trunk flexion, trunk flexion at initial contact, and peak knee valgus were significant between the two groups during the cutting maneuver. No significant difference was observed between the two groups in other variables. The results of this research indicated some kinematic pattern alterations in individuals with non-specific CLBP during the unanticipated cutting maneuver. Therefore, to prevent secondary injuries and exacerbation of back pain in athletes, it is recommended to take the non-specific CLBP of athletes into account and investigate the possible causes of its occurrence and treatment.

Keywords: Anterior cruciate ligament**,** Cutting maneuver, Low back pain, Biomechanics, Athletes

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INTRODUCTION

Nonspecific chronic low back pain (CLBP) is a common injury in sporting activities. Many athletes continue to exercise and compete due to its long-term and lack of clear pathology of nonspecific CLBP [1,2]. On the other hand, the effect of CLBP on proprioception, perception of posture and finally postural stability and decreased range of motion (ROM) in hip joint [3] and the lower back can cause secondary injuries in the lower extremities such as the anterior cruciate ligament (ACL) injury [4,5].

Knee injuries, especially the ACL injury, are among the most common sports injuries that cause physical, financial, and psychological costs to athletes and sports teams [6]. ACL rupture is one of the most common sports injuries, accounting for about 15% of football-related injuries in athletes between the ages of 15 and 40 [7]. Studies show that about 70% of the ligament injuries occurred due to non-contact mechanism [8]. Several studies have shown that the prevalence of ligament injuries is directly related to the type of sports [9,10]. Athletes in fields such as basketball, volleyball, squash, football, American football, and handball will be more vulnerable to these injuries [9]. The common aspect of these sports is the rapid and sudden change of directions along with the decrease/increase of acceleration in the closed kinetic chain, known as cutting maneuver. Cutting maneuver, which involves sudden changes in the closed motor chain, is used in many individual and team sports and is one of the main causes of non-contact ACL injuries [11].

Several studies have shown that CLBP can affect proprioception, postural control, and postural sense; lower limb kinematics significantly decrease in individuals with CLBP compared to healthy people [12,13]. Moreover, Individuals with CLBP have shown deficits in reaction time, coordination and ROM compared to healthy individuals [14]. These changes in trunk control and stability in the lumbar area will affect lower extremity function.

One of the factors affecting the loads on the knee joint during perturbation movements such as cutting maneuver is the trunk position [15]. Reducing the trunk flexion and performing cutting maneuver with the right position of the trunk causes the hip and knee joints to be extended, which may increase the knee valgus force with axial pressure, and thereby putting the ACL at injury risk [16]. Research shows a low association between lumbar and pelvic angles in patients with CLBP during trunk flexion in which the trunk flexion movement decreases in patients with CLBP [17]. In addition, there is a lack of postural sense of knee joint in patients with non-specific CLBP, which also shows a close relationship between knee joint function and lumbar spine.

According to the above, athletes with non-specific CLBP can be expected to exhibit different kinematic patterns during the cutting maneuver compared to those without non-specific CLBP. Moreover, research has shown that athletes have more pain tolerance than non-athletes and can continue their activity by ignoring pain [18]. This pain coping strategy may help athletes continue to exercise with pain, but does not fully demonstrate that injured athletes exhibit the same pattern as healthy athletes during activity. The motor apparatus can often use an injury response based on its priorities about chronic and injury-free pain, and these injury reactions are associated with changes in motor parameters. This emphasizes the importance of studying and comparing ACL injury risk kinematics patterns during an unanticipated cutting maneuver between athletes with and without non-specific CLBP.

MATERIAL AND METHODS

Study design

The present study is a cross-sectional study.

Participants

Twenty (10 with non-specific CLBP and 10 without non-specific CLBP) professional or semi-professional female athletes (basketball, volleyball, tennis, squash, football, handball) were purposefully selected. Inclusion criteria included athletes who had at least three years of training experience in sports such as basketball, volleyball, futsal, squash, tennis and handball between the ages of 20 to 30 years and did not experience any acute injuries in the spine and lower limbs, especially ankle aspirin, ACL or meniscus injuries. None of the subjects had observable musculoskeletal abnormalities such as genu varum/valgum or flat foot. Athletes in the group with CLBP had at least 3 months since the onset of their LBP symptoms and reported a maximum 2 on the visual analog scale. The sampling method was purposeful and available and the sample size was obtained according to the G*Power with an effect size of 0.9, 0.8 power and 0.05 Alpha. The results showed a sample consisting of two groups of 12 individuals that due to the coronavirus pandemic, this study was performed with two groups of 10 individuals. This research was approved by the Ethics Committee of the University of Tehran with the number. IR. Ut. SPORT. REC.030/1397. All participants provided written informed consent prior to study procedures.

Procedure

To evaluate the kinematic of the knee, ankle joint and lower back, Vicon motion analysis with 8 cameras and Naxos motion analysis software with a sampling rate of 240 Hz were used in the biomechanics laboratory of the Rehabilitation School of Shahid Beheshti Medical Sciences University.

The lower body Plug-in Gait marker model includes 16 reflex markers in both lower extremities, which were placed in ASIS, PSIS, femoral trunk, external epicondyle, leg trunk, lateral malleolus, heel and head of metatarsophalangeal joint along with a three-branch cluster with 4 markers on L3 vertebrae (Figure 1).

For the correct and identical implementation of the test, the extent of the test was designed and plotted on the ground. A distance of 7 meters and two angles of 35° and 55°, which determined a range of 45°, was provided to perform the cutting maneuver (Figure 2).

To make the direction of the cutting maneuver unanticipated, the test taker used two lights as a visual stimulus to determine the path of the participant. If the right light turns on, the participants prop the right foot and move to the left side, and if the left light turns on, the left foot is propped and move to the right side.

Participants completed a written consent form and the personal information form. Participants with nonspecific CLBP also completed the Oswestry Low Back Pain Disability Questionnaire.

Anthropometric characteristics such as height, weight, leg length, and wrist diameter were measured and recorded. Participants warmed up for 5 minutes before performing the test. Dominant leg was determined by ball shoot. Reflex markers were placed on the participant's body and to ensure proper implementation of the test, they were instructed on how to run the test.

To make the direction of the cutting maneuver unanticipated, participants performed the maneuver 3 times to the right and 3 times to the left, but finally data for maneuvers in which the support leg was the dominant leg were recorded and used. If a marker was removed from the body during the test or the test was not properly performed, the test was performed again.

Each participant ran the 7-meter path at the maximum speed possible, and along the path based on the light stimulus showing the left or right side, supported his left or right leg and then changed the direction to the opposite direction. This test was repeated 6 times so that 3 times the left light and 3 times the right light was unpredictably turned on.

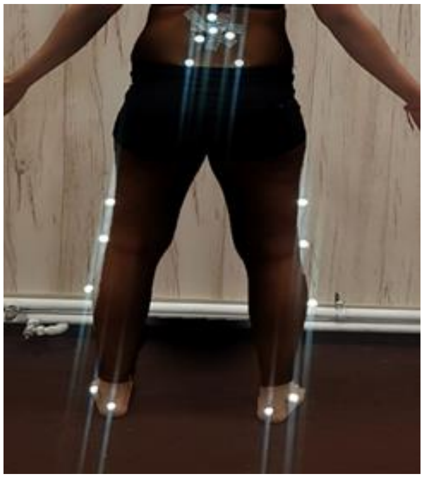

Figure (1). Marker placement

Figure (2). Extent of the cutting maneuver performance

Outcome

Knee joint angles including knee flexion, knee valgus, tibia internal/external rotation and trunk flexion were measured at initial contact and the maximum values in the dominant leg during the stance phase.

Data analysis

Data were described as mean±SD. Shapiro Wilk statistical test was used to determine the normal distribution of data. Independent t-test and Mann-Whitney U test were used to compare the outcome between groups. SPSS version 26 was used to analyze the data. The significance level was set at 0.05.

RESULTS

Table 1 shows participants' characteristics. Table 2 shows the results of independent t test for all variable measured between two groups; Figure 3 shows the ensemble average curves of measured variables for all variables measured.

Table1: The anthropometric characteristics of participants in each group

Variable	Group	Mean ± SD	N
Age(years)	No CLBP	25/60 ± 1/50	10
	CLBP	24/7 ± 2/4	10
Height(cm)	No CLBP	163/60 ± 4/40	10
	CLBP	163/90 ± 4/77	10
Weight(kg)	No CLBP	60/80 ± 4/36	10
	CLBP	61/70 ± 3/80	10

Abbreviation. CLBP: Chronic low back pain

The results showed that there are no significant differences for knee flexion and tibia internal/external rotation at both maximum and initial contact values during the unanticipated cutting maneuver between female athletes with and without non-specific CLBP.

The results showed that there is a significant difference in peak knee valgus between the healthy group and those with nonspecific CLBP; however, knee valgus at initial contact was not significantly different between the two groups. The results showed that the group with non-specific CLBP performed the unanticipated cutting maneuver with lower peak knee valgus than those without nonspecific CLBP ($p<0.05$).

The results showed that there is a significant difference in trunk flexion at initial contact and peak trunk flexion during the unanticipated cutting maneuver between female athletes with and without nonspecific CLBP. The individuals with nonspecific CLBP showed lower peak trunk flexion and lower trunk flexion at initial contact than those without nonspecific CLBP ($p<0.05$).

Table 2. Results of Independent t-test for variables measured between two groups

variable	Group	Mean ±SD	P
Knee flexion at initial contact	No CLBP	16.69± 7.53	0.090
	CLBP	24.09 ± 8.65	
Peak knee flexion	No CLBP	47.24 ± 6.82	0.444
	CLBP	49.36 ± 3.73	
Knee valgus at initial contact	No CLBP	4.43 ± 4.44	0.234
	CLBP	2.15 ± 2.67	
Peak knee valgus	No CLBP	14.39 ± 5.45	0.001
	CLBP	3.77 ± 4.55	
Trunk flexion at initial contact	No CLBP	10.05 ± 8.01	0.011
	CLBP	2.066 ± 4.37	
Peak trunk flexion	No CLBP	20.57 ± 5.62	0.001
	CLBP	6.80 ± 2.05	
Tibia rotation on the femur at initial contact	No CLBP	4.73 ± 5.90	0.064
	CLBP	9.80 ± 6.4	
Peak tibia rotation	No CLBP	8.53 ± 6.91	0.337
	CLBP	12.75 ± 7.66	

Abbreviation. CLBP: Chronic low back pain

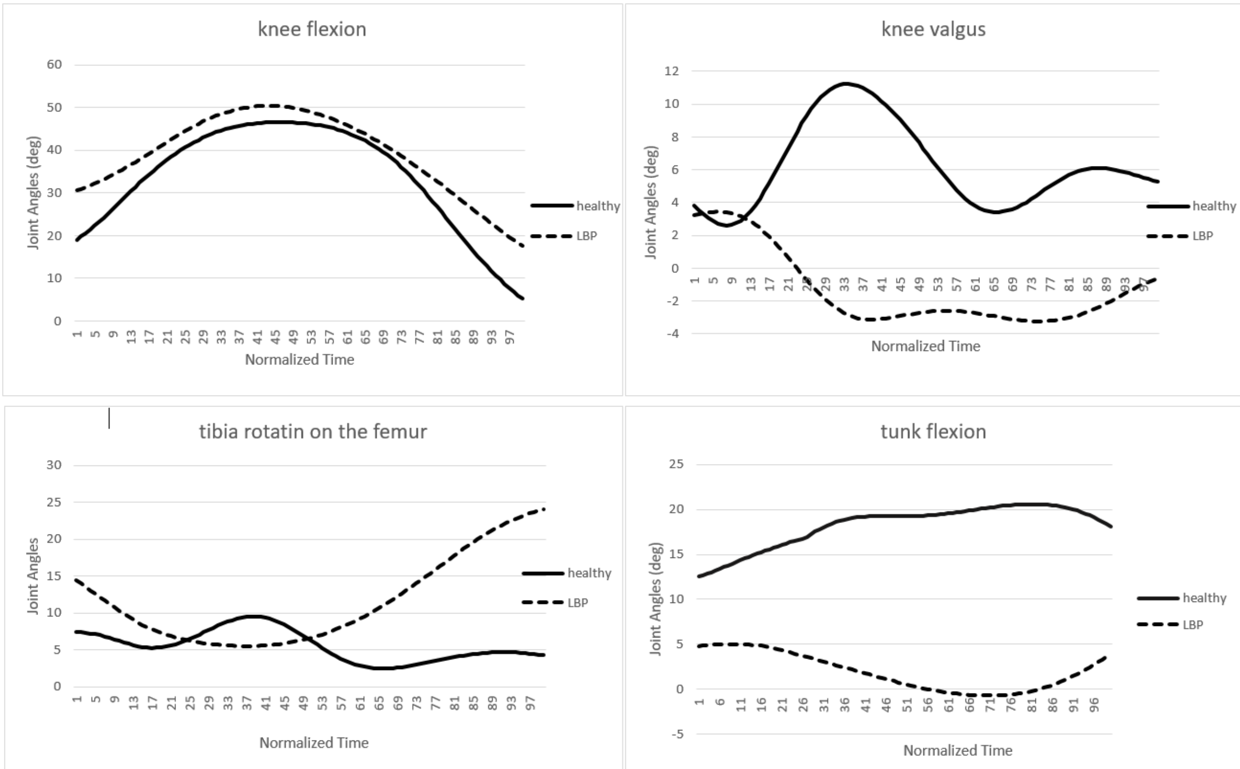

Figure (3). Ensemble average curves of measured variables for two groups, with 0% representing heel strike and 100% toe-off. Solid curves = nonspecific CLBP, dashed curves = without nonspecific CLBP.

DISCUSSION

The results of this study showed that female athletes with and without non-specific CLBP showed significant differences in some of the risk patterns of ACL injury including peak knee valgus, trunk flexion at initial contact and peak trunk flexion. However, in other risk patterns including internal/external tibia rotation and knee valgus at heel contact and their peak, there was no significant difference between female athletes with and without nonspecific CLBP.

The relationship between hip ROM and lumbopelvic rotations with nonspecific CLBP is a bilateral relationship [19]. It has been shown that a decreased hip ROM is associated with nonspecific CLBP [19]. While the mobility of the hip is reduced, repetitive hip movement can transfer external forces from distal to proximal segments. These movements repeatedly increase the load and compensatory movements in the lumbar, increasing LBP [19,20].

Cutting maneuver and sudden rotations are the main causes of non-contact ACL injuries [11]. A study examining the external forces on the knee during running and cutting maneuvers showed that flexion and extension are similar to normal but the forces exerted through valgus, varus, internal, and external knee rotation are significantly high. Therefore, a combination of external torques applied to the knee joint during the stance phase, especially at angles 0 to 40° flexion, can cause a high risk of ACL and lateral ligament injury in the absence of appropriate neuromuscular strategies to deal with these forces [21]. Another study showed that athletes with nonspecific CLBP had lower knee flexion angle than healthy athletes; however, there was no significant difference between the two groups for hip adduction, hip internal rotation, knee valgus and trunk extension. They acknowledged that decreased knee flexion during the landing maneuver increased the risk of ACL injury in individuals with LBP compared to healthy individuals [22].

The position of the trunk in the sagittal and frontal plates has a significant effect on the kinematics of the lower extremity during the cutting maneuver [23]. The rotation strategy happening in the frontal and horizontal plane of lower limb during the cutting maneuver, which causes displacement of center of gravity, increases the probability of ACL injury. Whyte et al. stated that the frontal and horizontal plane rotation strategy is a necessary strategy during rapid maneuvers, including cutting maneuver [24]. Of course, increased trunk deviation and decreased neuromuscular control of the trunk cause instability during perturbation maneuvers such as cutting maneuver and are associated with ACL injuries [15]. In particular, the increased and uncontrolled lateral trunk flexion significantly increases frontal plate loads such as knee abduction on ACL [15,24]. Therefore, reducing the trunk flexion and performing perturbation maneuvers with the right position of the trunk cause the hip and knee joints to extend, which will increase the knee valgus force with axial pressure, thereby increasing the risk of ACL injury.

Limited and asymmetric hip internal rotation ROM may be one of the reasons for the significant reduction of knee valgus in athletes with nonspecific CLBP [19,20]. The hip internal rotation is one of the most common and necessary movements during cutting maneuver which causes knee abduction [25]. Assuming that individuals with nonspecific CLBP show limited active hip rotation compared to healthy individuals, one of the reasons for the significant decrease in knee valgus in the subjects of the present study is the reduction of hip movement, but considering that the present study has not measured hip rotation, it cannot be definitively commented on this issue. According to current evidence, the causal relationship between LBP and changes in the lower extremity motor control cannot be clearly expressed [26]. It may also be possible the hypothesis that decreased hip internal rotation ROM and increased stiffness in the knee joint can increase the load on the lumbar area during physical activity, thereby increasing the risk of LBP [19]. Therefore, further research in this area as well as measurement of hip rotation in individuals with nonspecific CLBP during this maneuver can help make a better decision regarding this relationship.

CONCLUSION

The results of this study showed that female athletes with non-specific CLBP show similar kinematic patterns during unanticipated cutting maneuver with those without non-specific CLBP in knee flexion, tibia internal/external rotation and knee valgus at initial contact. However, there is a significant decrease in trunk flexion and peak knee valgus during cutting maneuver in athletes with non-specific CLBP. This can be expressed by the limited movement caused by CLBP, injury reaction and fear of pain from re-injury.

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Institutional Review Board Statement: The study protocol was approved by the ethics committee of the University of Tehran, Tehran, Iran.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data will be available at request.

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مقایسه ی الگوهای خطرزای کینماتیکی آسیب رباط متقاطع قدامی (ACL) در طی مانور برشی پیش بینی نشده در ورزشکاران با و بدون کمر درد مزمن غیر اختصاصی

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چکیده

ورزشکاران مبتلا به کمردرد مزمن غیراختصاصی احتمالا دارای الگوهای کینماتیکی متفاوتی در حین مانور برش نسبت به افراد سالم هستند. هدف از این پژوهش بررسی الگوهای خطرزای کینماتیکی آسیب رباط صلیبی قدامی در طی انجام مانور برشی پیش بینی نشده در ورزشکاران دارای کمردرد مزمن غیراختصاصی و مقایسه ی آن با ورزشکاران سالم بود. آزمودنی های این پژوهش شامل ۲۰ ورزشکارزن (۱۰ورزشکار سالم و ۱۰ ورزشکار دارای کمردرد مزمن غیراختصاصی) بودند که همگی آن ها در رشته های ورزشی که مانور برشی، از حرکات رایج در آن است، شاغل بوده اند. آزمودنی ها مانور برشی پیش بینی نشده را بر اساس جهتی که محرک بینایی مورد استفاده توسط آزمون گیرنده به آن ها نشان داده می شد، انجام دادند. از سیستم آنالیز حرکت سه بعدی برای جمع آوری داده های فلکشن زانو و تنه، والگوس زانو و چرخش تیبیا به روی فمور در لحظه ی برخورد پا با زمین و در حداکثر مقدار آن استفاده گردید. داده های کینماتیکی توسط نرم افزار نکسوس شرکت وایکان پردازش شدند. از آزمون تی مستقل در نرم افزار SPSS در سطح معنی داری ۰/۰۵ برای مقایسه متغیرها بین دو گروه استفاده شد. نتایج تحلیل آماری نشان داد که حداکثر فلکشن تنه و فلکشن تنه در لحظه ی برخورد با زمین و همچنین حداکثر والگوس زانو بین افراد با و بدون کمردرد مزمن غیراختصاصی معنادار بوده است. اما در سایر متغیر ها تفاوت معناداری بین دو گروه مشاهده نشد.

نتیجه گیری: نتایج این تحقیق حاکی از تغییر برخی الگوهای کینماتیکی افراد دارای کمردر مزمن غیراختصاصی نسبت به افراد سالم در طی مانور برشی پیش بینی نشده است. بنابراین توصیه می گردد که برای پیشگیری از آسیب های ثانویه و تشدید کمردرد در ورزشکاران، کمردرد های غیراختصاصی ورزشکاران را جدی گرفته و به بررسی دلایل احتمالی بروز و درمان آن پرداخته شود.

واژه های کلیدی: رباط صلیبی قدامی، مانور برشی، کمردرد مزمن، بیومکانیک، ورزشکار