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Comparison of Coordination and Coordination Variability of Lower Limb Joints during Cross Side-Cutting in Athletes with Chronic Groin Pain and Healthy Athletes

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Original Article

Abstract

Introduction: Chronic groin pain is a common and painful condition resulting in impaired performance and loss from participation in sports. High prevalence rate, complex anatomy, and long-term rehabilitation are among the challenges of this injury. Despite extensive clinical and medical studies in this field, groin pain in athletes remains unknown in terms of its biomechanical indicators, especially coordination and variability. Therefore, this study was conducted with the aim to compare lower limb joints' coordination and coordination variability between athletes with chronic groin pain and healthy athletes in the side-cutting maneuver.

Materials and Methods: The present research was conducted on 28 young football players (14 people in the chronic groin pain group and 14 people in the control group). Motion analysis cameras were used to collect 3D kinematic data of the lower limb joints. The coordination and coordination variability of hip-knee and knee-ankle joints in 3 planes were calculated using the continuous relative phase (CRP) method. Independent t-test was used to compare the two groups.

Results: Subjects with chronic groin pain have more out–of–phase movement in hip-knee coordination in the frontal plane, more significant variability in hip-knee and knee-ankle coordination in the frontal plane, and thigh-knee coordination in the horizontal plane.

Conclusion: The results of the present study show a decrease in coordination and an increase in the variability of lower limb coordination in subjects with chronic groin pain, which may lead to compensatory strategies, thus changing the distribution of forces, and resulting in pain and secondary injuries.

Keywords: Groin; Kinematics; Pain

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Introduction

A groin injury is prevalent in a wide range of competitive and non-competitive activities, particularly in multi-directional movements, acceleration and deceleration, impinging (striking), jumping, and landing (1, 2). Numerous studies have been conducted to explain the cause and risk factors of groin pain, such as the imbalance between the hip adduction muscles and the weakness of the lower abdominal muscles, asymmetry in the pelvis, and misalignment syndrome (such as knee injury and impingement). These previous studies have pointed out the direction of its movement, excessive internal or external rotation of the foot, the inequality of the length of the leg (structurally and functionally), and inappropriate shoes (3, 4). Moreover, abnormal muscle activity and wrong movement strategies lead to prolonged and chronic damage (5).

The assessment and management of groin pain in athletes has been a challenging issue, and this issue is due to the anatomical complexity of the hip and pelvis (6, 7). Moreover, groin pain itself may cause pain and damage in other body parts. A study was conducted to perform cause assessment of asymmetric knee loading in patients with advanced unilateral hip osteoarthritis

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(8). The results showed that one of the major causes of asymmetric loading was walking habit changes in response to chronic hip pain and its consequent structural damage. Groin pain accounts for 2% to 18% of all sport-related injuries (9, 10). Sports involving rapid changes in speed and direction or requiring more physical contact activity have more significant groin and hip vulnerability (11). These sports include ice hockey, American football, wrestling, fencing, and soccer matches (12). Injury caused by groin pain is a significant problem in football, which may lead to averting or even leaving sports activities (13-15). It has been reported that in men's football, chronic groin pain accounts for 19% of all injuries, 68% of which is caused by damage to the thigh adductor muscle. Poor planning, insufficient training and preventive measures, and the lack of correct diagnostic evaluation result in the chronicity and recurrence of this condition (16, 17).

A study on 695 football players indicated that 49% of the players experienced groin pain at least once during a season, and this pain lasted for more than 6 weeks in 31% of the players (1). Studies have shown that pain affects muscle function and movement patterns. Pain is a potential protective mechanism on performance-related movements for the prevention of further injury (18).

Athletes with chronic groin pain often experience anatomical pain at one or several points in the groin area. Many clinical and pathological studies have been conducted on chronic groin pain (19, 20). A study compared the muscle activity and co-contraction ratio of selected trunk and thigh muscles between people with chronic groin pain and healthy people during walking activity. This study showed that muscle activity and co-contraction ratio change with the changing of direction in people with chronic groin pain, which may lead to compensatory strategies and motor control deficits (11, 21-23). This finding may contribute to predicting the occurrence/mechanism or recurrence of chronic groin pain in people with such a history. Another study also showed that in athletes with chronic groin pain, there have been limitations in internal rotation of the hip joint, external rotation of the hip, and the range of abduction movements (24, 25). Despite ample clinical and comprehensive studies on groin pain, the biomechanical indicators, coordination, and variability examinations that will result in rehabilitation assessment in athletes have not been addressed (26-28).

Movement coordination indicates the ability to select or create movement and the degree of freedom to perform a task (29). Coordination is a functional indicator and may provide information about joint tension (30). Lack of or decrease in movement coordination can lead to abnormal movement patterns, compensatory movement patterns, or various sports injuries (31). Considering that the coordination between the joints is a necessary characteristic of a normal function and this is necessary based on the regular rhythm or order of the common action of the joints to perform daily tasks correctly and without injury, it is evident that as the movement becomes more complicated and/or more complex, coordination between joints or movement rhythm becomes more complicated and even more prominent (30). Variability in biomechanical parameters is one of the methods of examining movement control in the mechanics of the human body, which is examined from different theoretical perspectives (29). Variability in human movement can be defined as the natural variation in movement control strategies used when performing multiple task repetitions. Bernstein aptly described this phenomenon in 1967 as "repetition without repetition" (32). Conventionally, in biomechanical analysis, variability is considered an error in movement, where the individual tries to reproduce the same movement and fails (32). However, intra-individual variability in movement patterns in repetitive actions (e.g., step cycle) is now defined as a fundamental feature of any movement that allows adjustment to the stresses imposed on the body. Thus, variability is thought to have a functional role in musculoskeletal injuries (33, 34). Although, there is ample evidence that the biomechanical analysis of active movements, such as walking with or without changing direction, running, and sudden turning, are essential for improving the movements' functionality, there is not sufficient data available on coordination and variability of coordination in maneuvers.

Therefore, this study was conducted to compare coordination and variability of kinematic coordination and kinetic variables of lower limb joints between athletes with chronic groin pain and healthy people in the lateral cutting maneuver.

Materials and Methods

The current research was a semi-experimental and comparative study. The statistical population of this research included the male players of the first and second football leagues of the country. Using G-power software for the independent t-test, and considering a power of 0.75, significance level of 0.05, and effect size of 0.5, the sample size for each group was calculated to be 14 people (35). In this study, an available and purposeful sampling method was used. The study inclusion criteria for the group with anterior groin pain were having unilateral anterior groin pain for more than 4 weeks in the upper part of the fixed head of the adductor muscle on the pubic bone, groin pain after physical activity, positive squeeze test, lack of presence of any pain in the adjacent muscles or hip joint in the past 6 months, participation in sports and physical activity despite the presence of pain. The study inclusion criteria for the healthy group were no history of any lower-body injury in the last year, negative squeeze test, and general health of the body (4).

First, the process of conducting the test and the generalities of the research plan were fully explained to the participants. Then, they were asked to complete and sign the consent form and personal information form before the test. They were also assured that their data would remain confidential and that they could withdraw from the research process at any time. All participants were asked to use the same shoe model to perform the lateral shear test on the ground and force plate. The force plate and space calibration tests were performed minutes before the participants entered. Then, the examiner measured the subject's height and weight using digital scales and calipers, and recorded them in their individual information form. The participants warmed up for 5 minutes with a treadmill and did kinetic movements emphasizing the lower limbs. Then, they were asked to perform the lateral cutting task with the injured leg. Subjects performed the task several times as a test, and then, 7 main runs (38-41). Kinetic and kinematic data were recorded during lateral cutting using 8 Vicon cameras (model T20s; Vicon Peak, Oxford, UK) with a sampling frequency of 250 Hz and a Kistler force plate (model 9281; Kistler Instruments, Winterthur, Switzerland) with a sampling frequency of 1000 Hz (42-44).

Before testing reflective markers unilaterally on selected areas, including the first and fifth metatarsal, second metatarsal joint, inner and outer ankle, posterior part of the heel, inner and outer epicondyles of the knee, and anterior iliac spine and posterior iliac spine, 2 clusters were placed on the thigh and leg. Markers were tracked in Vicon software, and their 3D coordinates were extracted. The raw data of the coordinates of the markers were filtered using a fourth-order Butterworth low-pass filter with a cutoff frequency of 10 Hz (44). The contact time of the foot with the force plane was calculated using the vertical force data of isolated ground reaction and the 3D angles of the hip, knee, and ankle joints during the contact phase using Visual3D software (C-Motion Inc., Germantown, MD, USA). Then, the coordination and variability of the hip-knee and knee-ankle joint coordination were calculated in 3 planes using the continuous relative phase (CRP) method according to the article by Hamill et al. (45). The angular velocity of the hip, knee, and ankle joints was calculated by deriving the angular position for each data point (46). The position and angular velocity data were normalized to 100 points in time, and their amplitude values were between -1 and 1. These normalized positions and angular velocity vectors were drawn relative to each other for the hip, knee, and ankle joints. For each joint, the phase angle was calculated as the angle formed between a line from the origin to each data point and the horizon line. Then, the coordination between two joints was defined as the difference between the phase angles of the two joints in each percentage of the step. Furthermore, coordination variability was calculated as the standard deviation of coordination between 7 runs at each data point. Finally, 100 coordination data points and variability were averaged (46).

Data are described as mean and standard deviation. The normality of the data distribution was checked using the Shapiro-Wilk test, and the independent t-test was used at the significant level to compare the results between groups. Moreover, statistical analysis was performed using SPSS software (version 22; IBM Corp., Armonk, NY, USA).

Results

The demographic characteristics of the participants are presented in table 1. The statistical results showed no significant difference in age, height, weight, and body mass index (BMI) between the two groups.

The results of the comparison of coordination and variability of coordination between the two groups are presented in table 2.

Table 1. Comparison of anthropometric characteristics of the participants

Variable	Groin pain group	Control group	P
Age (year)	22.70 ± 2.00	23.50 ± 3.20	0.330
height (meter)	1.78 ± 4.27	1.75 ± 6.74	0.180
weight (kg)	76.07 ± 10.75	73.63 ± 7.88	0.524
Body index mass (M*2/KG)	24.26 ± 2.88	23.28 ± 2.62	0.941

BMI: Body mass index
Data are presented as mean ± standard deviation (SD)

Table 2. The coordination and variability of coordination between the groin pain groups and the healthy group

Variable	Groin pain group	Control group	t	P
Sagittal thigh-knee coordination	-70.99 ± 6.47	-66.89 ± 11.08	-1.142	0.265
Sagittal Knee-Ankle coordination	69.09 ± 10.40	69.12 ± 11.68	-0.006	0.995
Frontal thigh-knee coordination	-21.92 ± 19.24	-2.53 ± 22.54	-2.319	0.030*
Frontal Knee-Ankle coordination	-24.94 ± 26.05	-44.99 ± 21.90	2.073	0.050
Horizontal thigh-knee coordination	-7.86 ± 30.39	-9.46 ± 28.86	0.126	0.901
Horizontal Knee-Ankle coordination	2.77 ± 45.22	14.71 ± 33.40	-0.746	0.463
Sagittal thigh-knee variability of coordination	15.00 ± 4.70	13.90 ± 5.58	0.536	0.597
Sagittal Knee-Ankle variability of coordination	15.77 ± 4.81	15.49 ± 5.45	0.135	0.894
Frontal thigh-knee variability of coordination	38.40 ± 10.33	28.28 ± 0.66	2.621	0.015*
Sagittal Knee-Ankle Variability of Coordination	46.19 ± 6.23	36.08 ± 14.94	2.242	0.035*
Horizontal thigh-knee Variability of Coordination	55.44 ± 18.04	38.20 ± 22.53	2.121	0.045*
Horizontal Knee-Ankle variability of coordination	37.42 ± 12.24	30.68 ± 16.89	1.148	0.263

*P < 0.05

Data are presented as mean ± standard deviation (SD)

The independent t-test results showed that hip-knee coordination in the frontal plane is significantly higher in the group with chronic groin injury than in the group of healthy individuals. In addition, no significant differences were observed in other coordination points between the two groups. The results showed that individuals with chronic groin pain have significantly higher variability in hip-knee coordination in both frontal and horizontal planes and in knee-ankle joint coordination in the frontal plane compared to healthy individuals.

Discussion

In the present study, the coordination and variability of the coordination of the lower limb joints was compared between athletes with chronic groin pain and healthy athletes. Our results showed a higher degree of out-of-phase movement (simultaneous movement of two joints in the opposite direction) in hip-knee coordination in the frontal plane and an increased variability of hip-knee coordination in the frontal plane, knee-ankle coordination in the frontal plane, and hip-knee coordination in the horizontal plane in the athletes with groin pain compared to the healthy athletes. In this study, participants in the control group (athletes without chronic groin pain) demonstrated greater Iso-phase (coordination) in hip-knee coordination in the frontal plane than participants with chronic groin pain, which indicates a good movement pattern in the healthy participants and an irregular movement pattern in the participants with chronic groin pain. Coordination is the ability of athletes to control the change of direction and generate force to perform movements (47). Studies show that increasing variability or degrees of freedom and out-of-phase movement patterns can indicate a compensatory strategy in the movement control system to adapt to and control a new movement pattern (48).

Changes in the range of motion of the hip joint in people with chronic groin pain have been documented (49, 50). This action may be explained as a compensatory mechanism to reduce the anterior contact force of the hip joint and limit pain during walking or changing direction (3). Due to the close kinematic relationship between the joints of the body, especially the joints that are anatomically connected, any limitation in one joint can affect the other joints and change the coordination between two joints (51). In line with our data in this study, Mansourizadeh et al. showed decreased coordination in hip and trunk joints in rugby players with chronic groin pain (52).

Other results of the present study showed that the variability of thigh-knee coordination in the frontal plane, knee-ankle coordination in the frontal plane, and thigh-knee coordination in the horizontal plane was higher in the participants with groin pain compared with the healthy group. Conventionally, in biomechanical analysis, variability is considered an error in movement, where the individual tries to reproduce the same direction and fails (33, 53).

According to the general theory of motor control, changes in movement may indicate inappropriate neuromuscular motor control that leads to uncontrolled actions, excessive stress, and injury (53). In support of this theory, studies have shown more significant variability in several groups with different injuries, including athletes with chronic groin pain (54), chronic ankle instability (55), and iliotibial band syndrome (56). Furthermore, in the context of the dynamic systems theory, it is assumed that reducing variability during movement may lead to repetitive loading on a specific structure, which results in excessive stress and, eventually, structural damage (57). Several studies have further supported the association between reduced variability and injury in various injury groups, including chronic ankle instability (58) and patellar tendonitis (59).

Likewise, a study using dynamic systems theory to explain damage and movement variability has proposed the "optimal" hypothesis. According to this hypothesis, there is a specific variability range for human movement, which is less or more variability than this range with an increased risk of injury associated (45). The higher level of movement variability evident in injured populations may reflect an unstable compensatory movement mechanism used to reduce the load on sensitive and painful tissues (60). Pain causes changes in the body at both central and peripheral levels and changes movement variability (60). This view is consistent with dynamic systems theory, which suggests that movement patterns are spontaneously generated through self-organizing processes due to multiple factors impacting the individual (e.g., task, person, and environment). Although such a change in movement mechanics may serve a short-term goal of prevention of pain or further injury, it is not ideal as a long-term movement solution. The results of this study are consistent with the studies that showed people with chronic groin pain practice a modified strategy during lateral incisions. This movement disorder in the joints during repetitive and long-term movements may lead to a disruption in the distribution of shear forces in the lower limb, which leads to an increase in the load on the joints of the lower limb and an increase in repeated pressure on the groin and thigh muscles (3, 9). In activities such as lateral cutting, these forces increase up to several times the body weight (3). In the absence of high strength and endurance capacity, structural overload and pain continue, and constant activity can lead to long-term pain and secondary injuries such as hip osteoarthritis, previously confirmed by imaging findings (3, 13).

Limitations

The major limitation of this study was that we had unisexual subjects. As a result, anatomical differences such as wider pelvis and lower center of gravity in women were not considered.

Recommendations

The use of inertial measurement unit (IMU) wearable motion analysis systems is suggested to record kinematic motion outside the laboratory environment in future research. Due to their easy portability, these sensors are beneficial for recording the players' performance during training outside the laboratory, which may generate data more comparable to actual performance during a competition. Moreover, evaluation of the movement patterns of the non-injure leg is strongly suggested. The monitoring of the effect of proprioception on groin pain injury along with measurement of coordination and variability coordination is also suggested.

Conclusion

The results of the present study show the disorder in coordination and the variability of coordination in athletes with groin pain, which might be the result of compensatory strategies that lead to a change in the distribution of forces, and may subsequently lead to structural overload and pain. This information may enhance medical examinations and rehabilitation exercises designed for people with groin pain.

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Authors' Contribution

Study design and ideation: Behnoud Jafarpour, Mehdi Khaleghi Tazji, Amir Letafatkar, and Ali Abbasi
Obtaining financial resources for the study: Behnoud Jafarpour
Scientific and executive support of the study: Behnoud Jafarpour and Mehdi Khaleghi Tazji
Data collection: Behnoud Jafarpour
Analysis and interpretation of the results: Behnoud Jafarpour, Mehdi Khaleghi Tazji, Amir Letafatkar, and Ali Abbasi
Specialized statistics services: Behnoud Jafarpour
Manuscript preparation: Behnoud Jafarpour, Mehdi Khaleghi Tazji, Amir Letafatkar, and Ali Abbasi
Specialized scientific evaluation of the manuscript: Behnoud Jafarpour, Mehdi Khaleghi Tazji, Amir Letafatkar and Ali Abbasi
Confirmation of the final manuscript for submission to the journal website: Behnoud Jafarpour, Mehdi Khaleghi Tazji, Amir Letafatkar, and Ali Abbasi
Maintaining the integrity of the study process from the beginning to publication, and responding to the referees' comments: Behnoud Jafarpour, Mehdi Khaleghi Tazji, Amir Letafatkar, and Ali Abbasi

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Conflict of Interest

The authors did not have a conflict of interest. Dr. Khaleghi, Dr. Letafatkar, and Dr. Abbasi have been working as associate professors at Kharazmi University since 2021. Behnoud Jafarpour has been studying at Kharazmi University since 2017 as a PhD student of Sports Biomechanics.

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