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Does athletic groin pain affect the muscular co-contraction during a change of direction

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ABSTRACT

Background: Groin pain is one of the common problems in multidirectional sports. It seems that abnormal muscular activity and improper movement strategy led to prolongation and high rate of this injury. Therefore, the aim of this study was to Comparing the Average amplitude of Electromyography (AEMG), co-contraction ratio (CCR) of selected thigh and thoracic muscle during turning in individuals with chronic groin pain and healthy individuals.
Methods: Surface electromyography was collected from the internal oblique/transversus abdominis (IO/TrA), multifidus (MF), adductor Longus (AL) and gluteus Medius (GM) for AEMG and CCR analyzed in 16-males with LSGP and 16-controls in four motion phases during 11 cycles of gait coupled with turning.
Results: Results revealed that in the AEMG apart from the third phase in the muscle of the IO/ Tr. A muscle and in the second phase in the MF muscle in the trunk and in the third phase in the muscle of the AL and the fourth phase in the GM foot Left There was a significant difference in other phases. There was a significant difference in the CCR, except in the second phase of the trunk and the fourth phase of the left foot in the rest of the phases.
Conclusions: It seems that in athletes with LSGP, have selective muscular activation and CCR have during turning, that may be resulting in compensatory strategies and movement control defects, which may be a useful tool to predict LSGP occurrence in players with a history of groin pain.

1. Introduction

Pain in the groin and hip area is one of known injuries caused by playing in football codes (as in soccer [1] and rugby [2]). According to a recent study's finding conducted on 695 football players, 49% of these players reported having pain in the groin and hip, of whom 31% had been suffering from this pain more than six weeks [3].

The Long-standing symptoms of the hip and groin pain are mainly caused by the common activities, including changing direction quickly and frequently, sprinting, kicking during training or races [4,5], which can result in time-loss, and even end of career [6,7].

Turning and changing direction are considered as challenging motions which require moving and rotating in the body segments toward a new direction while it is to maintain dynamic stability [8]. Turning correctly is known as with rotating hip timely toward a new direction, which this practice is realized by neuromuscular control and appropriate activities of lumbopelvic and hip muscles [9].

Co-contraction is a mechanism used to ease the accuracy in body movements and stability in joints [10]. To quantify this mechanism, Surface electromyography (sEMG) has been proposed to be used [11].

According to research, as people are not able to activate and apply proper co-contraction patterns or they adopt improper strategies in applying the modified pressure (e.g. in reducing or enhancing the spine stability), they can most likely show symptoms and signs of motor control disorder [12,13]. Also, unresolved (or uncontrolled) motor control disorder contributes to begin, continue and recur the pain symptoms.

Hip and pelvis muscles' activation can play an important role in changing movement patterns and occurrence of groin pain [14–16]. Among the muscles which can play a key role in a favorable movement during turning, internal oblique/transversus abdominis(IO/TrA), multifidus(MF) [17–19], adductor Longus(AL) and gluteus Medius(GM) [9,16] can be mentioned as the important ones of which related activities and CCR are very likely to cause stability in the lumbopelvic, and motion control strategy [20,21].

Although no direct survey has not been found to explore the muscle activation in participants with the groin pain, but in the functional tasks, including Active Straight Leg Raising and Standing Hip Flexion,

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individuals with the LSGP demonstrated delay in onset of TrA [22], imbalanced the activation ratio of AL-GM muscles and low activation of GM muscle [16].

Imaging studies have indicated some traces of pubic bone marrow edema, formation of osteophyte in the pubic symphysis region and transformation of adductors given excessive stress in this region which can imply disorder in motor control and muscular imbalance [14,22]. Furthermore, Kinematic studies have shown instability in pelvis and other segments during the functional tasks as well as in the change of direction [14,15,21,23].

Researchers suggest that this motor control disorder may result in an increase in load and stress on the pubic symphysis, hip and muscle tendon interfaces [14,24], in axial turning and/or changes in direction, in which, according to previous work, a load that is up to 12 times the weight of the body will be distributed across the pelvis to the lower limbs [15].

Turning is a suitable motion challenge [8] required by multi-directional sports and daily activities [25,26]. As well as one of the possible mechanisms of groin strain and pain [27,28].

By investigating the muscular activity as well as CCR during the gait coupled with frequent turnings in individuals with LSGP and comparing it with healthy individuals, one can obtain useful information about motor control strategies as well as the possible mechanism of LSGP. Therefore, the aim of the present study is to compare the AEMG, and CCR of selected thoracic and thigh muscles during turning in individuals with LSGP and healthy people. We assume that patients with LSGP have lower AEMG, CCR in MF, IO/TrA muscles as well as AL and GM muscles. Also, they have a different average activity and CCR in different phases in comparison to the control group.

2. Methods

2.1. Participants

In this cross-sectional study, 32 right-leg dominant subjects were recruited from the Tehran soccer and rugby club based on the inclusion and exclusion criteria, and by clinical assessment by a physical therapist. The subjects were divided into two groups: athletic unilateral groin pain (n = 16) (from soccer (56.25%) and rugby (43.75%)) and healthy control (n = 16) (from soccer (62.5%) and rugby (37.5%)). The subjects received a detailed explanation about the investigation prior to participation in this study and were requested to complete the sports medical information questionnaire as well as the individual information informed consent form approved by the XXX University ethics committee (No:XXX).

3. Inclusion/Exclusion criteria

Inclusion (LSGP):

1 LSGP: Active players in multi direction or at the club level in Tehran [22].
2 Sport-related, insidious onset groin pain that has been present for at least 6 wk [22].
3 Groin pain during or after sporting activities [14,27].
4 Tenderness on palpation of either the adductor tendons, their insertion onto the pubic bone, or the pubic symphysis(visual analogue pain scores, VAS ≥ 3; range 0–10) [27,22].
5 positive adductor squeeze test at 45° of hip flexion(visual analogue pain scores, VAS ≥ 3; range 0–10) [27,14].
6 Presence of groin pain during active adduction against resistance at the time of assessment(visual analogue pain scores, VAS ≥ 3; range 0–10) [27,22].

Inclusion (control):

7 Active players in multi direction or at the club level in Tehran [14,22].
8 Negative adductor squeeze test at 45° of hip flexion [14].

Exclusion (LSGP):

9 Groin pain that commenced as a result of an acute incident [22].
10 Surgery to their lower abdominal, hip or groin region [22].
11 Frank inguinal hernia [22].
12 History of low back or sacroiliac joint pain in the past year [22,14].
13 Neurological symptoms (i.e. pins and needles, tingling, and/or numbness) in the lower limbs [22,21,14].

Exclusion (control):

14 History of groin pain
15 Surgery to their lower abdominal, hip, or groin region, or a frank inguinal hernia [22].
16 History of low back or sacroiliac joint pain in the past year18,19
17 Neurological symptoms (i.e. pins and needles, tingling, and/or numbness) in the lower limbs [22,21,14].
18 any systemic disease that has an influence on functional ability e.g. Ankylosing Spondilitis, Scheuermann's disease [14].
19 Rheumatoid Arthritis, Muscular Dystrophy or Paget's disease.

3.1. Instrumentation

Electromyographic (EMG) data were collected using a wireless TeleMyo DTS (Noraxon Inc., Scottsdale, AZ, USA), and Myo-Research Master Edition 1.06 XP software (Noraxon Inc., Scottsdale, AZ, USA) was used for analyzing EMG data. The EMG signals were sampled at 1500 Hz. A band pass filter was used between 20 and 450 Hz and a notch filter was preset to reject 60 Hz. A physiotherapist who has more than 3 years of clinical experience in the musculoskeletal field was responsible for palpating carefully the specified anatomical landmarks of the participants for placement of surface electrodes.

Two surface electrodes with an inter-electrode distance of 2-cm were positioned on the IN/TrA, LM, ADD, and GM muscles. Two electrodes were placed in the middle of each muscle belly and parallel to the muscle fibers. The electrode sites were shaved and rubbing alcohol was used to reduce skin impedance. For recordings of the IN.O/TrA, the electrodes were placed approximately 2 cm medial and inferior to the right anterior superior iliac spine [29]. The electrodes sites for the LM were defined as the level of the L_5 spinous process on a line extending from the posterior superior iliac spine to the interspace between L_1 and L_2 [30].

For recordings of the AL muscle the electrode was placed four fingerbreadths distal to pubic tubercle over the bulk of the adductor muscles [31](Figs. 1 and 2).

For the GM, the electrodes were placed half-way between the highest point of the iliac crest and the femoral greater trochanter [32].

The heel strike events were detected by pelvic acceleration data according to the methods described by Chow et al (2018). A successful trial was defined as one containing a complete stride initiated with the right leg for 2 group.

Acceleration and EMG data were recorded simultaneously using an IMU system (MyoMOTION MR3, Noraxon, USA). The IMU on the pelvis was affixed to the sacrum (L_5-S_1) [33].

3.2. Procedure

Each locomotor trial consisted of three laps of a walking circuit. The circuit required both linera motion and a series of turns. Following multiple practice trials, the subjects were asked to walk barefoot along a 70 cm by 70 cm walkway (Fig. 1) at a comfortable self-selected speed and data were collected from seven successful trials of the circuit (at least 21 ipsilateral pivot turns in the defined turning area for analysis were captured). In each repetition of the circuit, the first turn was made by stepping into an outlined 70 cm by 70 cm area with the foot ipsilateral to the turn direction (hereafter referred to as the "turn limb") and turning briskly 90° to the ipsilateral side (Fig. 1). Cones outlined the turning area [8].

Fig. 1. Turning.
Stride cycle of an ipsilateral walking turn to the right. Stride cycle commences with initial contact of foot ipsilateral to turn direction (turn limb).
Re-orientation is achieved in part by a pivot on the turn limb. The stance phase of the turn ends with the initial contact of the foot contralateral to the turn direction and toe-off of the turn limb, and the stride cycle is completed by the second initial contact of the turn limb.

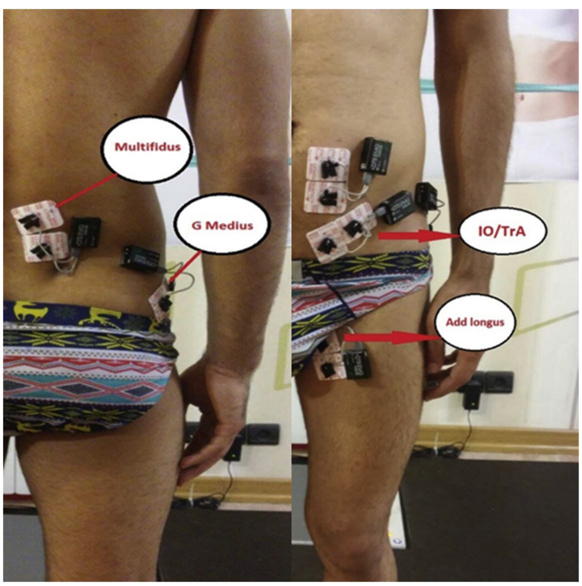

Fig. 2. Electrode Placement.

All participants spontaneously used a pivot strategy to complete the turn, with the change in direction being accomplished by a pivot on the turn limb [34].

For consistency each LSGP participant and their matched Control turned to the left side.

A visual analogue scale (VAS) was used to measure perceived levels of current pain [35].

3.3. EMG processing

Maximum value (MV) method [36] was used to normalize the EMG signals. This is a post-processing method applied to determine the peak value of EMG signal recorded for a distinct movement for a particular subject. Thereafter, this value is taken as a standard for other parts of the signal. That is, the other parts in the data series can be expressed as a percentage of the MV (%MV). This normalization procedure was used to ensure that a common ground is established when comparing signal from all subjects irrespective of their LSGP status. Sequel to acquisition of EMG signals, respective data for each movement made by each subject were normalized based on their individual MV. Then, the AEMG was recorded in 11 successive steps of turning, which reflects the muscle active level, was modeled as expressed in Eq. (1).

$$AEMG = \frac{\sum_{i=0}^{N} datai\ |i|}{N} \quad (1)$$

where i = 0, 1, 2,…,N, N = 100 is the total length of EMG data.

The CCR [37,38] was defined as the normalized integration of antagonist EMG activities divided by that of the total muscle activities. Which was recorded in 11 successive steps of the turning. Then the average AEMG was put in the formula. This can be expressed as:

$$CCR = \frac{AEMG_{antagonistic\quad muscle}}{AEMG_{agonistic\quad muscles} + AEMG_{antagonistic\quad muscles}}$$

Then, using the MATLAB software (MathWorks Inc., Natick, Massachusetts, USA), 11 steps were divided into four phases.

Muscle activity IO/TrA and MF were recorded bilaterally (right and left). Which was taken average from the total left and right activity.

3.4. Statistical analysis

Shapiro-wilk test was used to assess normal distribution of data; equality of variances was evaluated by Levene test. independent sample t-test was used to compare healthy and LSGP groups. For non-parametric data, differences between groups were compared using Mann-Whitney U tests. These analyses were performed using SPSS software version 23(Inc, Chicago,IL(. significance level was set at 0.05.

4. Results

There were no statistically significant differences between the groups for age, height and weight distribution, however the mean preferred turning speed was significantly lower in the LSGP group than in the control group (Table 1).

4.1. Electromyographic (EMG) activity

The results of independent t-test indicate that except for the third phase, there is a significant difference in the activity of muscles across other phases between the two groups ($p \leq 0.05$). Across all turning phases except for the second phase, LSGP group had a significantly lower EMG activity in comparison to the control group (Fig. 3A).

The results of Mann-Whitney test indicate that in phases 1,3, and 4, LSGP group had significantly lower CCR in comparison to the control group during turning ($p \leq 0.05$) (Fig. 3B).

Independent sample t-test indicated that except in the third phase, was significantly difference in muscle activity in the other(1,2and4) phases between the two groups ($P \leq 0.05$).

In all phases of turning, except in the phase 2, was significantly less muscle activity in the LSGP group than the control group (Fig. 4A).

The Mann-Whitney test indicate that in phases 1, 3 and 4 the LSGP group is a Lower than control group during turning ($P \leq 0.05$)

Table 1
Demographic characteristics of participants.

Groups factors	LSGP (n = 16)	Control (n = 16)	P Value
Age (year)	25.56 ± 2.36	25.25 ± 2.11	0.69
Height (cm)	179.56 ± 3.94	179.12 ± 4.04	0.75
Weight (kg)	78.25 ± 6.43	79.68 ± 6.85	0.54
VAS of groin pain at time of testing	2.93 ± 0.77	0.00	_

LSGP: Long-standing groin pain.
VAS: visual analogue scale.
[a]Significant mean differences, $P \leq 0.05$.

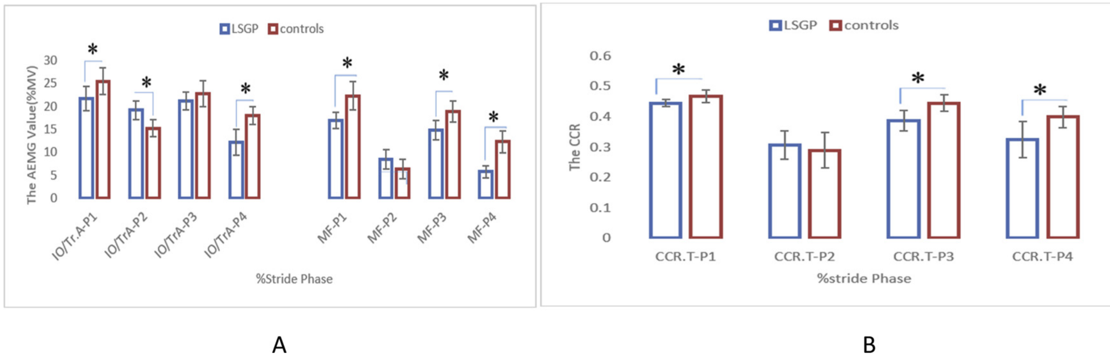

Fig. 3. Mean and standard deviation values of muscles Activation and CCR during turning.
P: Phase, IO/Tr.A: Internal oblique/Transversus abdomins muscle, MF: Multifidus muscle.
CCR: Co-Contraction Ratio, T:Trunk. Io/Tr.A to MF.
* indicates a statistically significant difference between groups (P ≤ 0/05).

(Fig. 4B).

The results of independent t-test show that in all of the four motion phases, there is a significant difference in the activity of muscles between the two groups ($p \leq 0.05$). The AEMG of the AL muscle was greater in all motion phases of the LSGP group in comparison to the control group. However, the mean AEMG of the GM muscle was greater in the first and second phases in the LSGP group in comparison to the control group. However, in phases three and four it was vice versa (Fig. 5A).

The results of Mann-Whitney test showed that the CCR ratio was significantly higher in the phases 1, 3, and 4 in the control group in comparison to the LSGP group ($p \leq 0.05$). However, in phase 2, this ratio was greater in LSGP group ($p \leq 0.05$) (Fig. 5B).

5. Discussion

The aim of this study was to compare AEMG and CCR of the selected muscles of the thoracic region (IN/TrA and MF) and thigh (AL and GM), during gait coupled with turning in four phases of motion in LSGP individuals and healthy control subjects.

We assumed that individuals with LSGP use a different pattern of muscular activity in comparison to health individuals during gait with turning, and the results support this hypothesis.

The main findings of this research suggested lower extent of activity and CCR of IO/TrA with MF in the thoracic region as well as increased activity and CCR of AL with GM in the thigh joint in individuals with LSGP in comparison to healthy subjects during turning.

Muscle activity and Co-contraction

In this study, AEMG and CCR of IO/TrA muscles with MF in the thoracic region were evaluated along with AL with GM muscles in the thigh joint in four motion phases during 11 cycles of gait coupled with turning. The results of comparison between the two groups showed that the AEMG of IO/TrA and MF muscles was significantly higher in all motion phases except for the second phase in the control group in comparison to the LSGP group. The results also implied high CCR of IO/TrA to MF in the control group in comparison to the LSGP group.

Further, the results obtained from comparing the AEMG of AL muscles and GM in the right and left leg as well as the CCR of these muscles suggested high activity of AL muscle in the LSGP group as well as elevation of CCR in the stance phase in the LSGP group.

Concerning the close connection between thigh-pelvis-vertebral column [39], proper functioning of the thigh muscles plays a significant role in transmitting force from lower limbs to the vertebral column and vice versa. Impairment in the activity of thigh muscles could possibly affect the biomechanical efficiency and performance of both lumbopelvic region and lower limbs [40,41].

Research performed on individuals with LSGP has also mentioned instability of the lumbopelvic region [21,22].

Among the key muscles playing a significant role during active motions for stability of lumbopelvic region are IO/TrA, MF, and GM muscles [17,42]. Concerning the importance of the stabilizing role and distribution of force in the hip joint and pubic symphysis, the activity of these muscles during active motions in individuals with groin pain needs further investigation [43,44].

During turning, the internal and external oblique muscles as well as TrA perform that turning as the main drivers of the thoracic region. Also, MF muscle provides an important component for stability of extension for the vertebral column during turning [17,19]. Without proper activity of MF during turning, without counteraction of oblique abdominal muscles, it will cause unwanted flexion of the vertebral

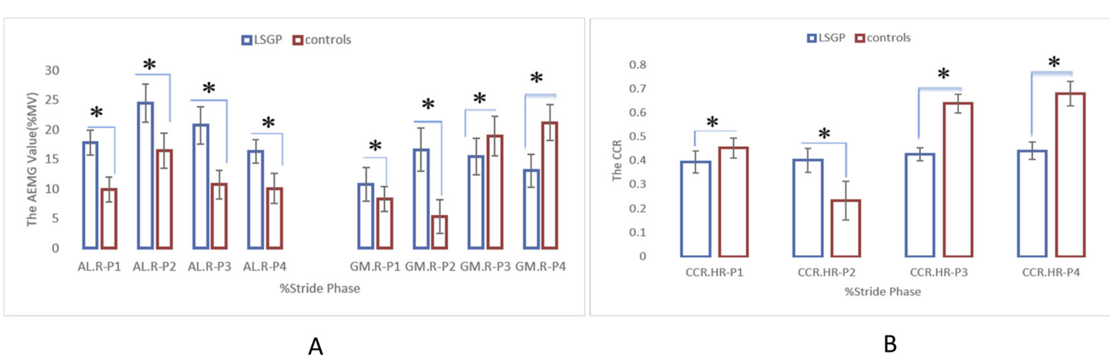

Fig. 4. Mean and standard deviation values of muscles Activation and CCR during turning.
P: Phase, R: Right Leg, AL: Adductor Longus, GM: Gluteus Medius.
CCR: Co-Contracton Ratio, H: Hip.AL to GM.
* indicates a statistically significant difference between groups (P ≤ 0/05).

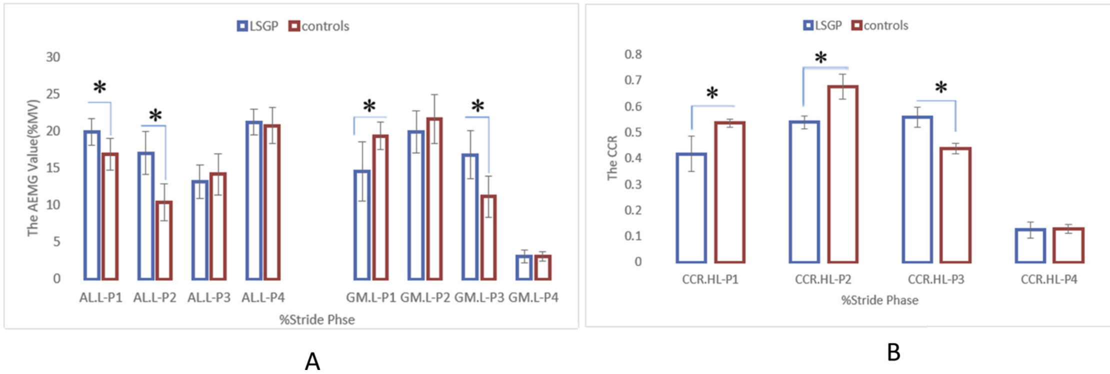

Fig. 5. Mean and standard deviation values of muscles Activation and CCR during turning.
P: Phase, L: Left Leg, AL: Adductor Longus, GM: Gluteus Medius.
CCR: Co-Contracton Ratio, H: Hip.AL to GM.
* indicates a statistically significant difference between groups (P ≤ 0/05).

column [17,45].

The results of this study suggested less activity of TrA/IO, MF, and GM muscles during turning among individuals with groin pain in comparison to healthy subjects.

In spite of the importance of MF role in lumbopelvic stability, it has been shown that the activity of this muscle is dependent on the activity of TrA muscle. Without proper activity of TrA muscle, MF cannot suitably play its role as the stabilizer of the lumbopelvic segment [46].

Therefore, with this assumption, one can find the reason of lumbopelvic and thoracic instability in the imbalance of lumbopelvic stabilizing muscles. In previous studies, delay in TrA activity [22]and reduction of MF size [47] and eventually lumbopelvic [14,21], and thoracic [15,48] instability have been shown.

On the other hand, GM can play a significant role in lumbopelvic stability. It has been shown that this muscle with the help of lumbopelvic muscles prevents adductor moment [16]. Improper activity of this muscle may lead to increased adductor moment and heightened load on the hip joint. This elevation of load during turning is multiplied up to several times of the body weight. In this regard, researchers have indicated that the imbalance between GM and AL is an important risk factor in AL overuse injury [16,49].

The results showed that AL muscle during rotation is more active in LSGP individuals, where possibly this increased muscular activity can be in response to heightened sympathoadrenal flow because of pain. Possibly, it leads to one of the reasons of diminished range of motion of the hip and in turn biomechanical changes in the hip and pelvis and eventually the thoracic region [50].

In addition, other influential factors such as weakness of abductors [16], thoracic instability [15]

lumbopelvic instability [15,21], and therefore impaired motion pattern and improper distribution of forces in pubic symphysis can result in increased stress on adductors [15,28]. This elevation of stress and activity may lead to enthesopathies of AL [51] and osteitis pubis [52] with MRI imaging studies also showing these signs [27,52,53].

In spite of less activity and co-contraction in individuals with LSGP, during the stance phase following turning (the second phase of the right leg and phase of left leg), this value was vice versa and increased significantly in both the thigh and thoracic segment. Although at IO/TrA to MF ratio it was not significant, the growth of this ratio was evident. This increase in co-contraction in the thigh and thoracic segment might be due to compensatory strategy for preserving postural imbalance following turning [11,54]. Probably, weakness and imbalance of muscles [50] and kinesiophobia [55] are also involved in this increased co-contraction.

Although increased co-contraction activity in the thigh may be useful in the presence of pain for stability of the hip joint, possibly with relapse of pain through increased extra load distribution on the hip joint, and pubic symphysis it could lead to intensification of pain, joint degeneration, and progress of the hip joint osteoarthritis [56].

6. Conclusions

This study was performed to investigate and compare the AEMG and CCR of selected muscles (IO/TrA and MF) and thigh muscles (GM and AL) during turning in individuals with LSGP and healthy subjects. During turning, individuals with LSGP had less muscular activity and CCR in the thoracic segment and GM. However, this value during the stance phase following rotation (second phase) was vice versa.

In spite of existence of evidence about improper stress and distribution of force in hip joint and pubic symphysis as well as adductor and abdominal muscles, no study had been performed for more precise investigation of this phenomenon. The results of the present study for clarifying this issue indicated that this muscle activity pattern may place football code players are greater risk for LSGP, which might account for the high levels of groin pain reported in this population.

These preliminary findings indicate that the prolonged change of direction protocol may be a useful tool for screening of football code athletes for risk of groin pain and also this information can be useful for clinical assessment and treatment of these individuals.

Declaration of Competing Interest

We confirm that there are no known conflicts of interest associated with this publication and there has been no financial support for this work that could have influenced its outcome. The researchers independently collected, analyzed, and interpreted the results and have no financial interests in the results of this study. Furthermore, dissemination of the results of this study does not constitute endorsement by the researchers or their institutional affiliations.

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