Original Article

Spatio-temporal Gait Parameters and Postural Balance in Soccer's Athletes with Ankle Sprain

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ABSTRACT

The purpose of the study is to determine the effect of sprain ankle joint in oscillation of center of gravity and symmetry of gait parameters in athletic players. Two groups were compared: 10 with unilateral ankle sprain symptoms *Sprain ankle group (SAG)*, mean 1 months after sprain ankle (Age= 21,56 ± 2,27, body mass = 68,93 ± 10,41 ±10, 21 kg, height 173,75 ± 7,54 cm), and 10 matched controls (CG), had bilateral non-injured ankles, no history of ankle inversion sprain or lower-extremity pathology, including fracture, sprain or arthritis. (Age= 20, 62 ± 1, 5, body mass = 71, 12 ± 8, 97, 97 kg, height =179, 75 ± 9, 52 cm). They participated voluntarily in our study. They are a member of the national elite and the follower of the collective physical activities. For gait, the Motion Analysis® system is used, to determine spatiotemporal variability of the lower limb during comfortable-speed walking. For Static balance assessment" Balance Master®" provides objective assessment of single-limb (right and left) stance postural stability with the eyes opened (EO) on the firm surface. This assessment quantifies the postural sway velocity of each leg. For spatiotemporal parameters, injured limb have a significant decrease in Length of step, Length of the strike, in single support time and in width step, but significant increase in cadence and in initial double support time (p<0,05). For one leg stance, results are expressed in terms of speed of oscillation of the center of gravity (CG), of uninjured (UM)/injured member (IM) for SAG and dominant (MD)/non-dominant (ND) Member CG, Oscillations of CG are statistically higher (p < 0.05) in injured, limb compared to healthy and control group. Sprain ankle leads to altered movement patterns and stability balance not only in injured limb but also in uninjured limb and relative to controls during both gait and static one leg stance. This study shows that alterations of gait patterns and postural balance can be correlated to deficits of the proprioceptive system. So proprioceptive training exercises can effectively stabilize an unstable ankle above for muscular and postural control.

Keywords: Balance, Soccer, Ankle, Sprain.

INTRODUCTION

Optimal athletic performance relies on the finely-tuned integration of the body's many systems to produce highly skilled dynamic movement. An injury may jeopardize an athlete's ability to perform and compete at a high level. One of the most common musculoskeletal injuries experienced in a physically active population is a lateral ankle sprain (LAS) (Beynnon et al., 2006). Due to the innocuous nature of this injury, some individuals do not follow a rehabilitation program designed by a healthcare professional (Wikstrom et al., 2013). Therefore the actual incidence of LAS may in fact be significantly higher. It has been suggested that lateral ankle instability is often associated with poor postural control, which can be defined as the inability to maintain stability above a narrow base of support in single-limb stance (Freeman et al. 1965; Tropp and Odenrick, 1988). However, no uniform consensus exists in the published literature.

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During a static one-legged stance task the displacement of the COG and the COG velocity in the medial/lateral and anterior/posterior directions can provide a measure of the individual's ability in maintaining stability in a single leg stance. Wikstrom (2010) conducted a systematic review and meta-analysis looking at 12 studies that assessed static balance for both the injured and non injured ankle post-injury. Their findings provided "strong evidence that balance is bilaterally impaired after an acutel lateral ankle sprain".

Being a joint of the lower extremity in close proximity to the body's base of support, the ankle plays an integral role in maintaining balance (Blackburn et al. 2000). It is believed that ankle proprioception is critical to balance during functional activities such as standing and walking (Robbins and Waked, 1988; Isakov and Mizrahi, 1997, Leanderson et al. 1996). Differences in stereotypical movement patterns observed in patients with sprain ankle suggest a contributory role for feed-forward neuromuscular control (Delahunt, et al 2006; Monaghan, et al. 2006). Under these conditions, compensatory movement patterns developed to limit pain and disability are thought to reorganize feed-forward movement strategies. Previous research has demonstrated that the sprain ankle leads to altered movement patterns relative to uninjured limbs and controls during gait (Delahunt, et al 2006; Hertel, 2002; Monaghan, et al. 2006).

Recently, researchers have compared the ankle kinematics of SA participants with healthy controls while walking (Liu et al. 2005; Mann and Hagy, 1988). Compared with healthy controls, sagittal-plane kinematics was altered during various aspects of the gait cycle, and these changes are believed to contribute to repetitive incidences of ankle sprains. The negative consequences of this interaction may be most eminent during dynamic activities, such as gait, which require the coordination of several joints and segments during cyclic transitions from loaded to unloaded conditions while maintaining a base of support (Delahunt, et al 2006; Hargrave, et al. 2003).

The contradictory results among previous studies and the lack of any studies that investigate the relationship between sprain ankle, one leg stance static balance and spatiotemporal gait patterns, it is reasonable to question the effect of this pathologic joint in oscillation of center of gravity and symmetry of gait parameters in athletic players.

In a previous study showed that a simple gait assessment of spatiotemporal parameters may objectively quantify the functional condition of patients with ankle sprain (Elbaz, 2014). To the best of our knowledge, there is missing data regarding the assessment and characterization of spatiotemporal gait of patients with SA. Therefore, this study had two aims. First, to examine alterations in spatiotemporal gait metrics in patients with SA compared to healthy participants. We hypothesized that athletes with SA will display deteriorated gait patterns compared to healthy participants. Secondly, quantifies postural sway velocity of Center of gravity on single limb stance trials in static postural stability. We hypothesized that Sprain ankle leads to altered stability balance in injured limb.

METHODS

Experimental Approach to the Problem

Ankle sprain is one of the most common injuries. Its mechanism is well known and has been the subject of numerous studies. Although joint structures are directly damaged and express biomechanical abnormalities, neuromuscular system could be injured leading to a modification of kinematic and postural responses. These modifications could affect the intra-limb coordination to produce a new motor behavior. A lateral ankle sprain can lead to compensations that continue to stress the injured ligaments (Wikstrom et al., 2013). This type of injury may lead to complications such as chronic ankle instability or post-traumatic ankle.

Osteoarthritis (OA) that adversely affects daily activities and sport performance.

Numerous instrumented measures of postural control in single-limb stance have been reported in the ankle instability literature, with instrumented force plate measures becoming the gold standard of assessment. Measures of postural control have been used in an attempt to assess sensorimotor deficits after acute ankle sprains. Also, the ability to objectively quantify the patterns of walking has improved our comprehension of normal and pathological gaits and efficiency of specific treatment modalities. The Quantified Gait Analysis is widely accepted as an excellent research tool that provides a strong support to assist in the diagnosis diseases of walking, which seeks to calculate the gait parameters, evaluate the mechanics of walking, and facilitate the identification of deviations with respect to the normal movement patterns.

Subjects

Two groups were compared: 10 with unilateral ankle sprain symptoms Sprain ankle group (SAG), mean 1 months after sprain ankle (Age= 21,56 ± 2,27, body mass = 68,93 ± 10,41 ±10, 21 kg, height 173,75 ± 7,54 cm), and 10 matched controls (CG), had bilateral non-injured ankles, no history of ankle inversion sprain or lower-extremity pathology, including fracture, sprain or arthritis. (Age= 20, 62 ± 1, 5, body mass = 71, 12 ± 8, 97, 97 kg, height =179, 75 ± 9, 52 cm). They participated voluntarily in our study. They are members of the national elite and followers of the collective physical activities.

Procedures

For gait, the Motion Analysis® system is used, consisting of six Eagle-4 cameras, coupled with a force platform AMTI® embedded in the ground. Both devices collected data synchronously at a frame rate of 100 H. A 3-dimensional motion analysis and KISTLER force plate system was used to determine spatiotemporal variability of the lower limb during comfortable-speed walking.

Before starting the data collect, the subjects became accustomed to the 10 m length walking paths for about 10 min to find a natural walk. The subjects were asked to walk at a self-selected pace on a10-meter walkway. All gait mean variables were calculated by averaging 5 strides from 10 trials or walks. In each trial, two consecutive strides from each side were recorded. 10 strides were considered an adequate sample.

Static Registration: The subject equipped with markers is first recorded in a static standing position on the force platform. This record has several objectives: it serves as a reference for the expression of kinematic results (this neutral posture defining the zeros of the joint angles) and the net joint forces and moments (expressed in terms of the subject's weight, measured by the force platform).

Gait recording: The subjects were instructed to walk at a comfortable speed ("as if you're on the street"). The subject then started walking before entering the field of cameras and continued after so that the steps of acceleration and deceleration were outside the analyzed field (Steinwender et al. 2000). In order for the movement to be as natural as possible, the subject kept his eyes fixed on the wall in front of him, and his starting position was adjusted forward or backward to increase the probability that the stance phase actually takes place on the force platform (Bohannon, and Williams Andrews, 2011). The trial was retained only if the stance phase of the dominant lower limb was correctly centered on the force platform. Five trials were recorded for each leg, this number being considered sufficient for healthy adults (Saleh and Murdoch, 1985), and two of them were randomly selected to be further analyzed. It has to be noticed that all subjects were wearing standard sportswear provided by the experimenter to cancel any influence of clothing and footwear.

Data processing: The 3D trajectories of markers were computed using Cortex 1.1 software and low-pass filtered (Butterworth order 4, cutoff frequency of 5Hz) to eliminate the high frequency noise. All kinematic variables were time-normalized as a percentage of the whole stride duration (0– 100%). The variables examined in the present study were time-distance parameters during gait.

Static balance assessment realized by The Balance Master® system provides objective assessment. The system uses a fixed, 18"x 60"dual force plate to measure the vertical forces exerted through the patient's feet. The long force plate enhances assessment and training capabilities. The interactive technology and clinically proven protocols allow the clinician to objectively assess patients performing a range of tasks, from essential activities of daily living through to high-level athletic skills. The objective data aids in the design of effective treatment and/or training program focused on the specific sensory and motor components underlying a patient's functional limitations.

The goal in managing balance and mobility disorders is the minimization of disability and improvement of functional performance. However, patients with similar pathologies frequently present significant differences in impairments and functional limitations. In view of these differences, patients with similar pathologies respond differently to a given treatment.

NeuroCom offers a comprehensive library of assessment protocols for quantifying the impact of impairments on a patient's ability to perform balance and mobility tasks required for safe and effective function in daily life. In short, the protocols provide the information required for accurate diagnosis of balance dysfunction and effective clinical management. All NeuroCom assessments are compatible with the World Health Organization (ICDIH-2) (Goebel, 2001) and disablement frameworks and have been validated by extensive scientific and clinical research (Zouita Ben Moussa et al. 2009).

We assessed single-limb (right and left) stance postural stability. Three practice trials were allowed in subject. The assessment quantifies postural sway velocity while the athlete stands calmly with one foot on the force plate. The relative absence of sway in the "hold still" position indicates better stability. They were asked to stand as still as possible for 30 s, the upper limbs along the body. The subjects were requested to maintain balance with the eyes opened (EO) on the firm surface. Subjects were instructed to focus their vision on a fixed-level target. This assessment quantifies the postural sway velocity of each leg. The sway velocity (in degrees per second) is given for all three trials. Subjects were allowed a 1-minute rest between tests (Zouita Ben Moussa et al. 2009).

In the study, all subjects provided informed consent. The research reported in this paper was undertaken in compliance with the Helsinki Declaration and the International Principles governing research on humans and animals.

Statistical Analyses

The analysis of the results is carried out with the statistical software package, SPSS (version 20 for Windows, Inc., Chicago, IL). The mean ± standard deviation is calculated for each measured parameter.

In every phase of our study, the normality of the distribution is analyzed by the test "Kolmogorov-Smirnov" to an error threshold at $p < 0.05$. The hypothesis of equality of means was tested by t-test "Student" for paired samples to detect differences between the patterns of gait. Using the Bonferroni-adjusted alpha, the statistical significance was set a priori at $p < 0, 05$.

RESULTS

According to the anthropometric data, both studied groups are statistically comparable. All the subjects suffer from a side sprain extent which is characterized by the achievement of the side collateral ligament.

For walking, the stance phase was defined as 0-62% whereas swing phase was defined as 63-100% of stride. Such findings to our knowledge are the first to demonstrate that for spatiotemporal parameters, injured limb have a significant decrease in Length of step, Length of the strike, in single support time and in width step, but significant increase in cadence and in initial double support time ($p<0,05$) (Table 1).

For one leg stance, results are expressed in terms of speed of oscillation of the center of gravity (CG), of uninjured (UM)/injured member (IM) for SAG and dominant (MD)/non-dominant (ND) Member CG. Supporting the classical findings of many investigations, oscillations of CG are statistically higher ($p < 0.05$) in injured, limb compared to healthy and control group (Table 2).

DISCUSSION

Fewer studies have investigated gait and postural alterations associated with sprain ankle in Tunisian athletes. The principal finding of our research is that sprain ankle leads to an asymmetry of gait for seven spatiotemporal parameters and to a deficit in postural control maintain in the injured leg flowing one month of injury. The foot and ankle complex is the base of the kinetic chain of the body. During locomotion, it is the first part of the kinetic chain that encounters weight acceptance, dampens shock during heel strike, directs forces throughout the remainder of the chain, and acts as the main power generator during the late stance phase of gait (Guskiewicz and Perrin, 1996). After an ankle sprain, there is a deterioration of the mechanical and neurological properties of the joint that may lead to alterations in gait (Hargrave et al. 2003, Hertel, 2002). Altered gait mechanics can place unnatural loads on the musculoskeletal system. Because the ankle is the foundation of the kinetic chain, any dysfunction could cause impairments to more proximal joints during locomotion. These alterations could predispose joints to compensatory injuries when considering the repetitiveness of the impact loads during locomotion (Chorba et al. 2010). However, there is little data in the literature describing the effect of ankle sprain on spatio-temporal gait parameters in injured athletes.

Table 1: Spatiotemporal variables of control Dominant Member (DM) and Sprain Ankle Group (** injured vs. uninjured and * CG vs. SAG: p<0,05)

Side	CG	EXP G	
	Dominant	Injured	Uninjured
Length of step (cm)	67,744 ± 0,484	57,703 ± 0,986	55,146 ± 2,274*
Length of strike (cm)	133,708 ± 2,911	115,565 ± 1,287	112,85 ± 1,779*
Cadence (pa/min)	110,80 ± 1,905	114,546 ± 5,454	116,619 ± 3,623*
Total Support Time (%)	59,68 ± 1,241	64,36 ± 0,364	60,92 ± 2,251
Swing Phase (%)	40,31 ± 1,241	35,636 ± 0,364	39,08 ± 2,251
Initial Double Support Time (%)	10,566 ± 3,243	8,54 ± 1,647**	12,891 ± 1,824
Single Support Time (%)	40,057 ± 0, 982	34,08 ± 2,25**	39,636 ± 0,364
Width step (cm)	18,107 ± 1,198	10,555* ± 0,125**	

Table 2: Speed of sway of center of gravity in injured vs. uninjured limb (*) compared to control group (**) (p: Signification) (*p<0, 05)

Speed of sway (deg/sec)	Test	Control group
Injured limb	0,97*± 0,13	0,72** ±0,09
Uninjured limb	0,89 ± 0,17	

Our results demonstrate that the gait of subjects who will sustain ankle sprain has typical characteristics. These can be summarized as follows: (1) decrease in length of the strip and of the strike, (2) increase in cadence, (3) a shorter initial double and single support them. We can suppose that our athletes with sprain ankle have an antalgic gait. The primary sign of an antalgic or painful gait is the reduced amount of time spent in the stance phase. This is because people do not want to spend any more time than necessary on a foot that is causing them pain. While the stance phase is usually divided equally between the two legs, someone with a painful foot will spend substantially less "time" on the injured foot, perhaps only 20-30% of their gait rather than 50%. Another sign of painful gait is a decreased stride length, which results from patients not wanting to push off from their painful foot as powerfully as normal. So, one stride tends to be much longer than the other. Stance phase is necessary to the "weight bearing" phase, provides the stability of the gait and for accurate swing phase to take place. Willens et al. (2005) suggests that Total foot contact time was also longer in the inversion sprain group compared with controls. The findings of this study suggest that effective prevention and rehabilitation of inversion sprains should include attention to gait patterns and adjustments of foot biomechanics.

The relative significance of one joint's motion compared to the others varies among the gait phases. Also, a posture that is appropriate in one gait phase would signify dysfunction at another point in the stride, because the functional need has changed. As a result, both timing and joint angle are very significant. This latter fact adds to the complexities of gait analysis. Each of the gait phases has a functional objective and a critical pattern of selective synergistic motion to accomplish this goal. The sequential combination of the phases also enables the limb to accomplish three basic tasks. These are weight acceptance (WA), single limb support (SLS) and limb advancement (LA). Weight Acceptance is the most demanding task in the gait cycle. The challenge is the abrupt transfer of body weight into a limb that has just finished swinging forward and has an unstable alignment. Under these conditions, compensatory movement patterns developed to limit pain and disability are thought to reorganize feed-forward movement strategies (Erik et al. 2009). Whereas alterations in feed-forward neuromuscular control are likely responsible for the differences between subjects with CAI and healthy controls, the causal mechanism for these feeds-forward alterations are less understood.

It is possible that feedback deficits incurred in the period after the initial injury lead to alterations in the control of movement. Thus, the failure or inability to control a specific body part (i.e., Limb) would force the patient to reorganize movement patterns to compensate.

Also, it has been suggested that lateral ankle instability is often associated with poor postural control, which can be defined as the inability to maintain stability above a narrow base of support in single-limb stance (Freeman et al.1965; Tropp, 1988).

The assessment of one leg postural control proves that, in an injured limb, sway oscillation is greater than uninjured limb and compared to healthy. Our results are like those obtained by Friden et al. (1989), Guskiewicz and Perrin (1996) and Rose et al. (2000) indicating poorer postural control in the injured group than the uninjured group. Comparisons between the uninjured limbs of the injured group and the matched limbs in the control group revealed deficits in postural control were seen in both the injured and uninjured limbs of participants sustaining unilateral ankle sprains compared with the control group. This last idea reinforces the hypotheses that the healthy member can be altered following the reloading of the injured leg.

Sprain ankle leads to altered movement patterns and stability balance not only in injured limb but also in uninjured limb and relative to controls during both gait and static one leg stance. It seems theses alterations are correlated to deficits of the proprioceptive system after the ankle sprain

PRACTICAL APPLICATIONS

The reason behind this article was to advise patients to perform balance training on both ankles following a lateral ankle sprain. Proprioceptive training exercises can effectively stabilize an unstable ankle above for muscular and postural control. Increasing our knowledge with respect to potential residual deficits following a lateral ankle sprain may potentially improve rehabilitation protocols thereby reducing the risk of re-injury and the residual symptoms experienced by an athlete. Clinicians often rely on manual testing, simple measurement tools such as a goniometer, subjective assessment of strength and patient feedback during rehabilitation of an injury. Balancing exercises are often prescribed in a very general manner that may not effectively target the deficits an athlete is experiencing. Adding perturbations to challenge an athlete's postural stability may be appropriate but the parameters for these perturbations are unclear.

This type of data could help guide a therapist to provide very specific exercises that address specific deficits.

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