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ORIGINAL ARTICLE

Analysis of the Christiania stop in professional roller hockey players with and without previous groin pain: a prospective case series study

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Abstract

Purpose In skating, the sudden controlled turning and stopping can cause the overuse of muscles in the adductor region, altering the whole skating performance, causing muscular strains and, consequently, groin pain. The aim of the study was to describe the movement pattern of a group of professional athletes with previous groin pain experience compared to a no-groin pain group.

Methods A prospective case series study design was performed. Eight male quad hockey players (four have had previous groin pain) were recruited. Players were asked to perform the Christiania stop: muscles activity patterns and lower limbs kinematics were simultaneously acquired with an optoelectronic system and infrared cameras allowing a computerized three-dimensional motion recording.

Results Groin pain group showed lower peak values in kinematic parameters and the most frequent pattern of surface electromyography amplitude referred to adductor longus muscle, vastus medialis, tensor fascia latae and transversus abdominis. In the no-groin pain group, the most frequent pattern of surface electromyography amplitude referred to transversus abdominis, adductor, vastus medialis and tensor fascia latae.

Conclusion Previous groin pain experience could affect the task performance by a subject's unconscious attempt to preserve the groin area.

Keywords Kinematics · Surface electromyography · Muscles · Athletes

Abbreviations

CS Christiania stop
sEMG Surface electromyography system

Introduction

In USA, 19.5 million people participated in skating sports and 3.2 million of them play roller hockey [1]. Roller hockey comprises quad and inline skating, both resembling ice hockey skating, and the match demands of this sport include periods of physical activity and recovery interspersed with brief periods of sprinting; it was shown that the maximum heart rate in roller hockey reached values between 85 and 90% of HR_{max} and blood lactate concentration between 4.0 and 7.2 mmol [1–3]. Proprioceptive acuity, assessed by measuring joint position sense, is increased in roller hockey players than other team sport athletes [4, 5] and this enhanced proprioception could potentially contribute to injury prevention [6, 7]. However, in roller skating, as well as for ice skating [1], the sudden controlled turning and stopping can cause strain in the lower extremity resulting in unstable side-to-side balance for the mediolateral muscles of hip, knee and ankle [2]. Muscular strains may be caused by repetitive eccentric contraction attempting to decelerate the leg while skating or during stops [8].

The Christiania stop (CS) is the most abrupt stop in quad roller hockey, consisting of a rapid deceleration performed through a rotation of 90° of the pelvic girdle and a frontal rotation of the lower limbs of 90° with respect to the stopping direction [8]. The overuse of muscles in the adductor region during the CS may alter the whole skating performance causing muscular strains and, consequently, groin pain.

Groin pain is a common problem in athletes with a prevalence between 5 and 28% [9, 10] in all sports involving

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rapid acceleration and sudden direction changes [11]. Groin pain in elite hockey players is increasing [12], accounting for approximately 10% of all injuries [13]. Hockey players' muscle injuries can be painful and recurring especially during stops, needing long periods of rehabilitation [2].

Despite hockey's worldwide appeal, the lack of biomechanical studies is related to the difficulty in collecting data due to methodological limitations of conventional motion capture systems in large environments [14, 15]. The aim of the present case series study was to describe the Christiania stop dynamics in quad roller hockey players. Successively, we described the movement pattern of a group of athletes with previous groin pain experience compared to a no-groin pain group. Kinematics data and surface electromyography (sEMG) activity of the lower limbs were considered and described. This study could be a preliminary step towards the etiology of groin injuries in quad roller hockey players and be a basis for further clinical trials.

Methods

Subjects

Eight male professional adults of the Italian National quad hockey team with at least 15 years of experience, high level of skills and conditioning, training every day, were involved providing written informed consent to participate in this study. Exclusion criteria were: tobacco use, working use of medications, and medical conditions contraindicating physical exercise as diagnosed by the sports medicine physician. All subjects were requested to abstain from training before the data collection. Before performing the CS, anthropometric evaluation of body mass (kg), height (m), and body mass index (BMI, kg m^{-2}) was performed and all participants provided personal anamnestic data to the investigators to understand possible past injuries related to groin pain. Table 1 reports players' general characteristics.

Four players have had previous groin pain, while four have never had any groin problem in the past. However, none was affected by groin pain during acquisition.

Dominant and contralateral leg were considered for the analysis. All research activities were approved by the Institutional Review Board and were conducted in accordance to the Declaration of Helsinki; each subject provided written informed consent to participate to this study. The study was reported according to CAse REport (CARE) guidelines [16].

Procedures

All test sessions were conducted in the Motion Analysis Laboratory of Galeazzi Orthopaedic Institute, Milan, Italy. Muscle activity patterns and lower limbs kinematics during a CS were simultaneously acquired. An optoelectronic system (SMART-D; BTS Bioengineering, Milan, Italy) with eight infrared cameras (sample rate of 100 Hz) allowed the computerized three-dimensional motion recording. The system is integrated with a 16-channel wireless surface electromyography (sEMG) system, (FreeEMG 300, BTS Bioengineering, Milan, Italy) working with an acquisition frequency of 1 kHz. Twenty passive reflective markers were placed on the player's anatomic landmarks according to Davis protocol adapted to the skates worn [17]. The feet markers were glued to the skates in correspondence to the feet anatomical landmarks (heel and fifth metatarsus). Surface EMG electrodes were placed as recommended by the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) [18]. To assure inter-tester reliability, the same person applied all the markers and sEMG electrodes.

Participants were asked to perform CS task on a runway within the area monitored by the cameras.

The task was repeated three times per subject. Standard instructions on how to complete the CS were provided. Players had to start from a standing position and perform an all-out frontal skating sprint towards the center of the runway and practice the CS with their dominant leg (determined as the leg through which they would kick a ball).

Table 1 Baseline characteristics of the subjects included, divided into groin and no-groin pain

	ID	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)
Groin pain	1	42	74	179	23.10
	2	25	85	178	26.83
	3	23	73	173	24.39
	4	21	85	178	26.83
	Mean (SD)	27.75 (9.60)	77.75 (5.50)	179.75 (6.70)	24.11 (2.04)
No-groin pain	5	20	71	175	23.18
	6	23	74	176	23.89
	7	25	85	185	24.84
	8	25	84	174	27.74
	Mean (SD)	23.25 (2.36)	78.5 (5.07)	177.5 (5.07)	24.91 (2.01)

We considered the left CS as the stop where the left leg (dominant leg) is backward stopping and the right leg (contralateral leg) is forward closing the stop, while the right CS was the opposite.

The CS was isolated from previous skating (necessary to reach an adequate velocity) by analyzing the hips and pelvis markers' trajectories. The CS beginning was considered as the moment in which the pelvis marker of the non-dominant leg started the intra-rotation for stopping, while the CS ending as the moment in which the player stopped and was upright standing.

Statistical analyses

Kinematic variables of interest during the CS were hip flexion (lateral plane), hip internal rotation, hip adduction, pelvic rotation and knee flexion (lateral plane). Hip angles were calculated between pelvis and thigh markers, knee angles between thigh and tibia markers, while pelvic angles were calculated using the right and left anterior superior iliac spine (ASIS) markers. Means and standard deviations for subject characteristics and for kinematic variables were reported.

The sEMG activity of the following muscles was acquired: transversus abdominis, vastus medialis, tensor fascia latae and adductor longus on both sides. Since maximum voluntary contraction data were not available, a dedicated protocol for sEMG signal processing was created using Smart Analyzer® software (BTS Bioengineering, Milan, Italy). Raw data were band-pass filtered (20–450 Hz), rectified and low-pass filtered (3 Hz) to obtain the linear envelope of each signal. To identify the beginning of the activation, the mean EMG intensity at rest plus two standard deviations was used as threshold, according to Soderberg and Knutson [19] and peak values of every muscle were considered.

Three trials' data for each player were averaged for kinematics and muscles activity analyses. No statistical tests were used considering the descriptive intent of the study and the small sample size.

Results

Table 2 reports kinematics peak values (°) for dominant and contralateral leg of each player during a Christiania stop.

Groin pain group showed lower peak angle values in each kinematic parameter for both legs, except for the hip adduction of the contralateral leg, which is higher compared to no-groin pain group's value. Figure 1 presents kinematics data of two players' dominant leg during a CS cycle: the no-groin pain subject shows higher hip flexion, hip rotation, pelvis rotation and knee flexion during the entire CS cycle compared to the groin pain player.

Table 2 Mean and standard deviations of kinematics peak values (°) for dominant and contralateral leg of each player during a Christiania stop

Group	ID	Dominant leg (mean, SD)					Contralateral leg (mean, SD)				
		Hip flexion	Hip adduction	Hip rotation	Pelvic rotation	Knee flexion	Hip flexion	Hip adduction	Hip rotation	Pelvic rotation	Knee flexion
Groin pain	1	82.2 (2.83)	3.6 (0.78)	12.2 (0.49)	15.4 (1.98)	75.55 (2.9)	66.2 (3.6)	21.8 (3.68)	40.1 (2.05)	101.7 (0.35)	51.1 (1.5)
	2	69.2 (5.76)	9.23 (2.05)	22.8 (2.74)	16.8 (3.14)	66.93 (2.5)	48.6 (5.2)	15.2 (2.7)	15.4 (2.46)	99.2 (3.3)	44.7 (0.8)
	3	69.5 (4.8)	7.9 (3.4)	4.4 (3.3)	11.5 (1.8)	57.8 (8.74)	36.8 (4.5)	23.35 (3.73)	6.4 (4.8)	93.13 (2.95)	27.3 (1.09)
	4	80.8 (1.17)	14.5 (1.6)	5.43 (4.99)	21.9 (2.98)	77.95 (4.2)	38.6 (5.9)	16.37 (1.33)	8.27 ± 2.11	94.33 (1.06)	35.6 (2.74)
	Mean (SD)	75.42 (7.07)	8.81 (4.47)	11.3 (8.46)	16.41 (4.28)	69.56 (9.16)	47.56 (13.7)	19.17 (4.01)	17.55 (5.5)	97.11 (4.07)	39.6 (10.42)
No-groin pain	5	75.9 (2.3)	10.17 (1.22)	18.27 (4.7)	13.1 (1.6)	70.33 (4.9)	46.33 (1.16)	15.67 (1.10)	28.47 ± 1.00	103.9 (3.26)	40.9 (4.86)
	6	87.75 (6.15)	13.6 (2.76)	9.6 (3.9)	31.7 (23.1)	69.4 (1.70)	63.3 (16.85)	15.07 (5.55)	23.2 (14.7)	99.5 (13.49)	37.83 (3.84)
	7	94.7 (8.77)	5.1 (2.26)	20.1 (11.3)	3.45 (4.6)	81.4 (1.06)	61.15 (4.88)	15.05 (1.48)	34.9 (2.47)	92.1 (4.10)	59 (8.2)
	8	77.9 (1.27)	8.8 (0.28)	13 (0.14)	41.05 (1.3)	80.75 (0.6)	53.7 (2.19)	13.1 (15.7)	34.65 (0.64)	100.45 (2.05)	38.8 (0.85)
	Mean (SD)	83.1 (8.78)	9.5 (3.5)	15.58 (4.79)	22.3 (17.12)	74.9 (6.5)	56.57 (7.7)	14.9 (1.14)	28.85 (5.6)	99.4 (4.96)	42.69 (9.99)

The first four subjects have had previously groin pain

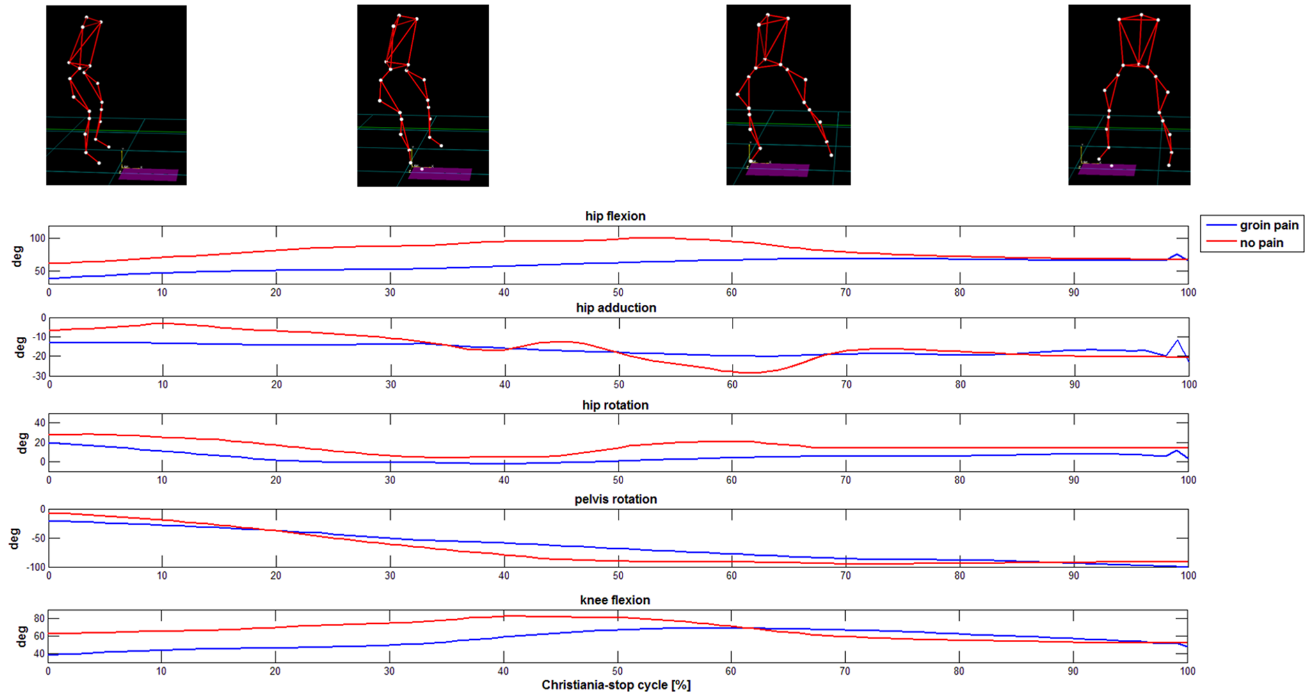

Fig. 1 Kinematics data of two players' dominant leg during a Christiania stop

The peak values of amplitude for each muscle during a CS are reported for both groups in Table 3.

Choosing to describe the most frequent pattern of sEMG amplitude in terms of magnitude of signal, i.e., from the highest to the lowest peak value, within group: in the groin pain group, the highest amplitude refers to adductor longus muscle, followed by vastus medialis, tensor fascia latae and transversus abdominis. On the contrary, in the no-groin pain group, the highest amplitude refers to transversus abdominis, followed by adductor, vastus medialis and tensor fascia latae. Concerning the contralateral leg, in both groups, the highest amplitude refers to tensor fascia latae and vastus medialis, while adductor longus and transversus abdominis are switched in groups.

Discussion

This case series study aimed to create a hypothesis regarding kinematic and muscle activity pattern in a group of athletes, i.e., roller hockey players, with previous groin pain experience compared to a no-groin pain group. Indeed, a different pattern of kinematics and muscles activity was found. Overall, kinematics data collected for the dominant leg in the groin pain group resulted to be of lower magnitude compared to the no-groin pain. Players with no history of groin pain seems to be more inclined to have the highest amplitude in the transversus abdominis during the CS task, while players with previous groin pain activated the adductors the most. The experience of pain perception could produce high levels of fear avoidance leading to dysfunction of tasks and/or development of chronic pain [20]. We suppose that in the groin pain athletes, the presence of previous pain could have affected the task performance due to a subject's unconscious attempt to preserve the altered groin area. Indeed, the stop movement is correctly performed by the core muscles, i.e., the transversus abdominis that anticipates the muscle activation in players without past pain condition in accordance with the literature [21–24].

Fear avoidance can occult central sensitization pain. The experience of pain shows specific neuroplastic changes in the peripheral and central nervous system [24].

The central nervous system assures the core stability by contraction of the transversus abdominis in anticipation of reactive forces produced by lower limb movements [25]. This means that the core muscle activity should precede lower extremity muscle activity in the temporal sequence of many athletic tasks in healthy conditions. Our findings might generate the hypothesis that players who experienced groin pain delay the activation of anticipatory postural muscles, i.e., the transversus abdominis, causing a lack of postural stabilization during the CS. However, a different study design with a larger sample size could help in understanding if injuries occur in athletes due to the muscles recruitment delay or the injury itself is a consequence of inadequate muscles recruitment. Previous

Table 3 sEMG peak values (mV) of both legs for each subject during a Christiania stop

Group	ID	Dominant leg (mean, SD)				Contralateral leg (mean, SD)			
		Transversus abdominis	Adductor longus	Vastus medialis	Tensor fasciae latae	Transversus abdominis	Adductor longus	Vastus medialis	Tensor fasciae latae
Groin pain	1	71.38 (3.05)	143.24 (9.36)	139.76 (19.25)	104.84 (37.88)	276.23 (27.33)	268.21 (25.71)	144.69 (22.05)	363.34 (63.91)
	2	32.33 (7.80)	278.53 (52.36)	53.86 (3.83)	40.72 (8.70)	43.91 (9.35)	125.95 (21.20)	285.58 (74.17)	484.71 (101.32)
	3	79.73 (25.34)	290.62 (44.69)	89.92 (23.22)	57.86 (13.90)	255.06 (38.01)	145.02 (56.90)	326.62 (65.52)	335.34 (27.74)
	4	83.16 (18.50)	30.6 3(7.34)	113.08 (48.67)	44.54 (7.40)	72.26 (11.88)	268.81 (28.47)	115.09 (23.03)	121.92 (20.29)
No-groin pain	5	130.62 (7.85)	169.88 (58.86)	98.41 (13.97)	99.32 (28.64)	108.81 (63.76)	171.62 (50.30)	214.84 (32.36)	450.32 (28.15)
	6	325.61 (134.65)	58.49 (15.94)	113.25 (27.12)	119.71 (39.67)	70.63 (19.59)	49.88 (11.94)	101.60 (27.07)	506.82 (59.67)
	7	118.07 (7.41)	81.32 (14.29)	74.48 (22.32)	44.20 (16.68)	45.04 (3.54)	196.00 (49.34)	135.27 (11.34)	131.56 (53.26)
	8	216.73 (55.98)	103.23 (27.65)	81.50 (21.74)	50.83 (13.71)	94.42 (17.88)	66.17 (22.12)	216.52 (24.45)	227.30 (48.04)

The first four subjects have had previously groin pain

studies have already demonstrated consistent delays in feedforward activation of the transversus abdominis muscle in people with musculoskeletal disorders [26, 27]. So, deficient neuromuscular core control of motion during athletic tasks may predispose athletes to injuries and pain [26]. However, how exactly the organization of core stability muscles is changed with pain is still unclear. Even if there is limited evidence that preprogrammed feedforward adjustments can be trained [27], it might be possible that isolated transversus abdominis muscle training could lead to changes in the activation patterns in quad roller hockey players. Future studies should investigate the real association among groin pain, injuries and core stability activation.

Transversus abdominis and core stability muscles have a central role in injury prevention [20]. Prevention of injuries is important in athletic training, but very little high-quality research evidence is available to guide the administration of specific injury prevention practices [28, 29], or prescribing precautionary training strategies and appropriate rehabilitative objectives [2, 30, 31].

Concerning the study limitations, the current literature is focused only on ice as well as inline skating hockey in which the athletic gestures are slightly different from the quad roller hockey. The small sample size might be seen as a limitation, as well as the study design, however, professional quad roller hockey players, with a well-documented injury history and background/training information, are more representative of this sport discipline than amateur participants. Other limitations are related to the sEMG acquisition technique due to the lack of baseline signals and normalization procedures. Nevertheless, the team recruited fairly represented the highest level of quad roller hockey players in Italy. However, we were not able to apply statistical tests due to the limited sample. Nevertheless, this is the first study investigating a usual task for quad roller hockey players placing the basis for the development of a new hypothesis.

Conclusion

This study represents the first step towards the movement analysis of quad roller hockey tasks. It seems essential that sport medical staff should recognize early on the weakness of their athletes' muscle and abnormal kinematics movements to prescribe preventive training strategies and appropriated rehabilitative programs. In addition, strength and athletic coaches, because of their expertise, are uniquely placed to develop both injury prevention and sport-specific agility skills programs that address the biomechanical deficits seen in quad roller hockey athletes.

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Compliance with ethical standards

Conflict of interest The authors report no conflicts of interest.

Ethical approval All research activities were approved by the Institutional Review Board (L3017, Ricerca Corrente) and were conducted in accordance to the Declaration of Helsinki.

Informed consent Each subject provided written informed consent to participate to this study.

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