Gait & Posture 58 (2017) 374–379

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Biomechanical differences between cases with suspected chronic exertional compartment syndrome and asymptomatic controls during running

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ARTICLE INFO

Keywords:
Exercise-induced leg pain
Chronic exertional compartment syndrome
Biomechanics
Anthropometry
Military training

ABSTRACT

Chronic exertional compartment syndrome (CECS) has been hypothesised, following clinical observations, to be the result of abnormal biomechanics predominantly at the ankle. Treatment of CECS through running re-education to correct these abnormalities has been reported to improve symptoms. However no primary research has been carried out to investigate the movement patterns of those with CECS. This study aimed to compare the running kinematics and muscle activity of cases with CECS and asymptomatic controls.

20 men with bilateral symptoms of CECS of the anterior compartment and 20 asymptomatic controls participated. Barefoot and shod running 3D kinematics and muscle activity of the left and right legs; and anthropometry were compared.

Cases displayed less anterior trunk lean and less anterior pelvic tilt throughout the whole gait cycle and a more upright shank inclination angle during late swing (peak mean difference 3.5°, 4.1° and 7.3° respectively). Cases demonstrated greater step length and stance time, although this was not consistent across analyses. There were no consistent differences in Tibialis anterior or Gastrocnemius medialis muscle activity. Cases were heavier (mean difference 7.9 kg, $p = 0.02$) than controls with no differences in height ($p > 0.05$)

These differences only partially match the clinical observations previously described. However, no consistent differences were found at the ankle joint suggesting that current running re-education interventions which focus on adjusting ankle kinematics are not modifying pathological aspects of gait. The longer step length is a continuing theme in this population and as such may be a key component in the development of CECS.

1. Introduction

Chronic exertional compartment syndrome was first described in 1956 [1]. It is an overuse condition presenting as pain in the lower limb, associated with the muscles contained within the myofascial compartments of the shank. The anterior compartment is most frequently affected [2]. While numerous studies have tried to understand the pathophysiology of CECS [3–6], few studies have tried to identify potential risk factors for CECS. The higher reported incidence of CECS in the military compared to civilian practice makes this population ideal for testing potential factors.

CECS is commonly defined as a condition where elevated intramuscular compartment pressure (IMCP) during exercise impedes local blood flow leading to ischaemia and impaired neuromuscular function within the compartment [7,8]. Two systematic reviews recently questioned the role of IMCP and the validity of its use in diagnosis [9,10]. However, we have since reported much improved diagnostic criteria for CECS using continuous IMCP measurement during exercise, thus confirming the intrinsic role of IMCP in this condition [11].

IMCP can be increased through changes in compartment compliance, compartment content or muscle activity [3,12,13]. We recently reported the finding that IMCP in patients is elevated on standing prior to exercise. This suggests that a structural component, presumably increased fascial stiffness, results in reduced compartment compliance [11]. Biomechanical factors have been considered to play a role in the development of CECS for a long time [14]. More recently CECS has been hypothesised, following clinical observations, to be the result of abnormal biomechanics predominantly at the ankle [15]. However, only one other group has investigated the role of movement patterns and muscle activity in the pathology and aetiology of CECS [16]. This study was focussed on skiing biomechanics and had a very limited sample ($n = 5$ cases); limiting the applicability to the wider population.

Conservative treatment through gait modification has recently been promoted as a viable option for CECS [15,17,18]. Forefoot running was first described as a possible treatment in a case report by Cunningham

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http://dx.doi.org/10.1016/j.gaitpost.2017.08.035
Received 20 February 2017; Received in revised form 20 August 2017; Accepted 27 August 2017

Table 1
Comparison of differences (ANCOVA) in temporal-spatial data between groups (*$P < 0.05$). N.B. All variables are normalised to leg length and therefore do not have units.

Normalised variable	BF/SHOD	L/R	F	P	Mean (Controls)	SE (Controls)	Mean (Cases)	SE (Cases)	Mean Diff
Step Length	BF	L	1.612	0.212	0.599	0.010	0.618	0.011	−0.019
		R	0.960	0.334	0.604	0.008	0.616	0.009	−0.012
	SHOD	L	4.720	0.036*	0.608	0.009	0.638	0.010	−0.030
		R	0.003	0.959	0.635	0.010	0.634	0.010	0.001
Step time	BF	L	0.015	0.903	1.148	0.012	1.150	0.012	−0.002
		R	0.050	0.825	1.185	0.013	1.181	0.013	0.004
	SHOD	L	2.621	0.114	1.154	0.013	1.186	0.013	−0.032
		R	0.760	0.389	1.230	0.014	1.212	0.014	0.018
Stance time	BF	L	2.170	0.149	0.764	0.013	0.792	0.013	−0.028
		R	4.254	0.046*	0.733	0.012	0.771	0.012	−0.038
	SHOD	L	0.565	0.457	0.821	0.015	0.837	0.015	−0.016
		R	4.418	0.042*	0.774	0.015	0.821	0.015	−0.047
Flight time	BF	L	2.225	0.144	0.422	0.016	0.388	0.016	0.034
		R	3.243	0.080	0.414	0.014	0.378	0.014	0.036
	SHOD	L	1.677	0.203	0.409	0.018	0.376	0.018	0.033
		R	0.397	0.533	0.381	0.017	0.365	0.017	0.016
Swing time	BF	L	0.910	0.346	1.570	0.023	1.538	0.023	0.032
		R	1.332	0.256	1.599	0.024	1.559	0.024	0.040
	SHOD	L	0.060	0.807	1.551	0.029	1.561	0.029	−0.010
		R	0.702	0.407	1.610	0.027	1.577	0.027	0.033

[19] that may reduce the anterior compartment muscle activity [20] and therefore pain. This has since been followed up by further case reports and a case series of ten US military patients [21–23].

We recently reported the kinematic and kinetic differences between CECS patients and controls during walking and marching [24]. Patients had greater ankle plantarflexion at toe-off and generated lower ankle inversion moments than healthy controls. However, patients typically also complain of pain during running; indeed running is the most common cause of pain within civilians [25]. All of our military patients describe their pain as stopping them from either marching or running; while 30% of these individuals describe pain stopping them from only one of these activities (unpublished data). We therefore aimed to identify the differences in the running biomechanics between patients with CECS and healthy controls.

2. Methods

20 male cases with symptoms consistent with CECS of the anterior compartment of the leg and 20 asymptomatic controls were recruited. The diagnosis of CECS was established from typical symptoms, with clinical examination and MRI excluding alternative pathologies. Controls were recruited from the UK armed forces. All participants gave informed consent. Cases were recruited from the Lower Limb Pain clinic at the Defence Medical Rehabilitation Centre prior to the provision of any gait advice. Ethical approval was granted by the MOD Research Ethics Committee.

The inclusion criteria were: Male; Aged 18–40 (representing the typical age-range of UK military service personnel); BMI < 35; and no lower limb length discrepancy > 2 cm. Cases required the following: symptoms of exercise-induced leg pain consistent with a diagnosis of anterior compartment CECS; a negative MRI of the affected limb(s); no diagnosis other than anterior CECS more likely, and the ability to run for short periods without pain limiting performance. All patients were assessed in a multidisciplinary clinic by a consultant in sport and exercise medicine and senior physiotherapist. This specialist clinic was specifically for patients presenting with exercise induced leg pain. Detailed history taking, including direct questioning and physical examination were used to determine the exact localisation of the patients' pain. This often included a symptom provocation test on a treadmill. Patients were only included in the study if their symptoms were purely localised to the anterior myofascial compartment. Controls were included when they were able to run for at least 20 min and had: no lower limb pain in the previous 12 months; no current pain at any site, including during exercise activities; and no reliance on orthotics.

Measurements of leg length, height and body mass were performed using a tape measure, stadiometer (SECA, UK) and medical grade scales (SECA, UK) respectively.

2.1. Kinematics and electromyography

Retro-reflective markers were placed on specific anatomical landmarks to form 15 body segments including the feet, shank, thigh, pelvis, trunk, head, upper arm, forearm and hand by the same operator. The head, upper arm, forearm and hand were not analysed as part of this study; these were not considered further. Data were collected using a 10 camera (4 × T160, 4 × T40-S, 2 × T10) 3D motion analysis system (Vicon MX system, Oxford Metrics Ltd., Oxford, England) at a sampling frequency of 120 Hz. A static calibration trial was first collected.

Participants walked barefoot on the treadmill for familiarisation, once happy the participant directed a member of the research team to increase the speed until they were at a comfortable running pace that they felt could be sustained for 15–30 min under normal circumstances. Once at the chosen speed this was maintained for a further 2 min. Only the final minute was used for analysis in order to allow gait to normalise to the running environment as much as possible. Five trials of five seconds of data were collected at five-second intervals in accordance with a similar previous study [26]. This process was repeated with participants provided with military issue training shoes (Hi-Tec Silver Shadow). Orthotics were not used during testing. A recorded trial was deemed suitable if it had minimal marker dropout and no major gait inconsistency on the part of the subject as judged by an observer, e.g. stopping or stumbling.

The pelvis and thigh segments were defined according to Wu [27], the shank segments were defined according to Peters [28] and tracked using the marker cluster recommended by Manal [29], the feet segments were a modified version of the foot flat option defined by Pratt [30]. The thorax was defined according to Gutierrez [31].

Electromyographic (EMG) data were collected using 4 wireless Trigno (Delsys Inc., Boston, MA, USA) sensors (16-bit Resolution; four 5 mm × 1 mm silver contacts; fixed 10 mm inter electrode distance) at a sampling frequency of 1200 Hz. Hair was removed from the EMG testing locations using a surgical razor. In order to reduce skin impedance, the skin was cleaned using an alcohol wipe and lightly rubbed so that the skin went light red [32]. EMG activity of the Tibialis anterior and Gastrocnemius medialis were recorded bilaterally during all movement trials and sensors placed according to the guidelines by