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Gait Assessment of Patients with Spontaneous Osteonecrosis of the Knee: A Retrospective Case Controlled Study

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Abstract

Background: The purpose of this study was to characterize the gait patterns of patients with spontaneous osteonecrosis of the knee (SONK).

Methods: Twenty-eight patients (16 females and 12 males) diagnosed with SONK with a mean ± SD age of 67.3 ± 8.3 years participated in this study. 27 age-matched healthy controls, mean ± SD age 64.6 ± 10.7 years, were also evaluated. All patients underwent computerized spatiotemporal gait assessment during level walking at a self-selected speed. Primary outcome measures were gait velocity, cadence, step length and single limb support.

Results: Significant differences were found between patients with SONK and healthy controls in all spatiotemporal gait parameters. Patients with SONK had a significant lower walking speed (66.4 cm/s compared to 107.0 cm/s, a 38% decrease), lower cadence (59.9 steps/min compared to 110.3 steps/min, a 46% decrease), shorter step length (43.5 cm compared to 58.0 cm, a 25% decrease) and lower single limb support values (31.1% of gait cycle compared to 39.6% of gait cycle). Furthermore, patients with SONK presented significant asymmetry between the involved limb and uninvolved limb in SLS (31.1% of gait cycle compared to 38.8% of gait cycle for the involved and uninvolved limbs, respectively).

Conclusions: Patients with SONK present alterations in spatiotemporal gait parameters compared to normal control, suggesting that gait is significantly compromised by the disease. Furthermore, significant asymmetry was found in several gait parameters between the involved limb and uninvolved limb of patients with SONK.

Keywords: Osteonecrosis; Knee; Gait

List of abbreviations

SONK: Spontaneous Osteonecrosis of the Knee; NSAIDs: Non-Steroidal Anti-Inflammatory Drugs; UKA: Uni-compartmental Knee Arthroplasty; TKA: Total Knee Arthroplasty; OA: Osteoarthritis; BMI: Body Mass Index; GC: Gait Cycle; SLS: Single Limb Support (%GC); DLS: Double Limb Support (% GC)

Background

Spontaneous osteonecrosis of the knee (SONK) is considered to be the most common form of osteonecrosis of the knee [1]. The incidence of SONK has been reported as 3.4% and 9.4% in persons older than 50 and 65 years of age, respectively [1]. However, the actual prevalence may be underestimated since many patients who present with end-stage osteoarthritis (OA) may have had occult undiagnosed SONK [2]. Historically, SONK was thought to occur secondary to ischemia, which would result in necrosis. However, recent evidence has demonstrated that it may be due to subchondral insufficiency fractures in osteopenic bone, with no evidence of necrosis [3].

Non-operative management of early stages of SONK includes treatment with non-steroidal anti-inflammatory drugs (NSAIDs), protected weight bearing, analgesics and bisphosphonate [4]. Surgical management includes joint-preserving techniques such as arthroscopic debridement [5] microfracture [6] and core decompression [7]. In end stage SONK, uni-compartmental knee arthroplasty (UKA) or total knee arthroplasty (TKA) are the most common treatment options [8,9].

The use of gait analysis as a clinical tool is well recognized [10]. It is used to assess the effect of various pathological conditions on biomechanical properties of the lower limbs [11-13], evaluate severity of disease [14] and determine the effect of different treatment modalitiesn [13,15-17]. Furthermore, gait analysis has been shown to be an objective measurement tool to assess pain, function and quality of life [18-20].

However, to the best of our knowledge, there is no data on the effect of SONK on the gait patterns of the patients. Assessing gait pattern of patients with SONK may add more knowledge on the pathomechanics of the disease. Therefore, the purpose of this study was to characterize the gait patterns of patients with SONK. The hypothesis tested was that the spatiotemporal gait parameters will be significantly lower than normal in this population.

Methods

This was a retrospective analysis of patients diagnosed with SONK. The research methodology was similar to other research works that examined patients with different musculoskeletal conditions [21-23]. Ethics committee approval was obtained at Assaf Haropeh Medical Center, Zerifin, Israel. The study is registered in clinicaltrials.gov (NIH protocol no. NCT00767780).

A search for patients diagnosed with SONK by referring physician was performed on the research database of AposTherapy Center in Herzliya, Israel. Between April 2009 and July 2015, 87 patients were referred to the center and were enrolled in the database. Inclusion criterion was SONK of the medial femoral condyle confirmed by MRI. Patients with a history of major trauma, predisposing factors of osteonecrosis, osteoarthritis, previous surgery to the knee excluding arthroscopy, knee arthroscopy <3 months were excluded from the study.

A total of 28 patients who met these criteria were identified (16 females and 12 males): mean age ± SD was 67.3 ± 8.3 years, mean ± SD height was 159.3 ± 22.0 cm, mean ± SD weight was 87.5 ± 20.8 kg and mean ± SD body mass index (BMI) was 33.1 ± 9.5 kg/m^2. Mean ± SD duration of symptoms was 6.3 ± 4.8 months. 27 healthy, age-matched, volunteers served as a control group (13 females, 14 males). Their mean age ± SD was 64.6 ± 10.7 years, mean ± SD height was 165.8 ± 7.3 cm, mean ± SD weight was 64.6 ± 10.7 kg and mean ± SD BMI was 25.4 ± 3.1 kg/m^2.

Following an extensive medical history anamnesis and clinical examination all patients underwent a computerized spatiotemporal gait evaluation (GaitMat system, E.Q., Inc. Chalfont, PA). Patients were asked to walk barefoot at a self-selected speed. Patients walked 3 m before and after the walkway mat to allow sufficient acceleration and deceleration time outside the measurement area. Four trials were conducted, and acquired data was stored for further analysis. The mean value of the four trials was calculated for each of the following parameters: velocity (cm/s), involved and uninvolved step length (cm), cadence (steps/min), involved and uninvolved stride length (cm), base of support (cm), involved and uninvolved swing (% gait cycle (GC)), involved and uninvolved stance (%GC), involved and uninvolved single limb support (%GC) (SLS) and involved and uninvolved double limb support (% GC) (DLS).

Data were analyzed with SPSS software version 21.0. (SPSS Inc. Headquarters, 233 S. Wacker Drive, 11th floor Chicago, Illinois 60606, USA). The significance levels were set at 0.05. The distributions of continuous variables were examined using the Kolmogorov-Smirnov non-parametric test. Data were presented as mean and standard deviation for spatio-temporal variables. Chi-square tests and independent t-tests were performed to compare the two groups (SONK and Control) for categorical and continuous variables, respectively. GLM univariate analysis was used to evaluate differences between the two groups, in spatiotemporal characteristics, controlling for BMI. To evaluate limb asymmetry (involved and uninvolved leg) in selected spatiotemporal gait parameters, the paired t-tests were used.

Results

The two groups, patients with SONK and healthy controls, were similar with regards to gender distribution, age and height (p=0.292, p=0.318, and p=0.197, respectively). Significant differences between groups were found in weight (p=0.001) and BMI (p<0.001). However, these differences did not affect the results of the study while controlling the gait results with BMI as a confounder.

Significant differences were found in all gait parameters excluding the swing and stance phase of the involved knee and the SLS phase of the uninvolved knee. The results are summarized in Table 1.

A comparison was made between the involved limb and uninvolved limb. Significant differences were also found between the involved limb and uninvolved limb of patients with SONK in swing, stance, and SLS (p<0.001 for all) (Figure 1). There were no significant limb differences in step length and DLS. There were no limb differences in the healthy controls groups.

	SONK	Controls	P
Velocity (cm/s)	66.4 ± 23.0	107.0 ± 19.3	<0.001
Cadence (steps/min)	59.9 ± 8.1	110.3 ± 10.5	<0.001
Step length – involved (cm)	43.5 ± 9.9	58.0 ± 6.5	<0.001
Step length – uninvolved (cm)	43.4 ± 11.1	57.8 ± 7.2	<0.001
Stride length – involved (cm)	87.0 ± 20.3	115.7 ± 13.5	<0.001
Stride length – uninvolved (cm)	86.9 ± 20.3	115.8 ± 13.9	<0.001
Base of support (cm)	7.3 ± 4.4	5.0 ± 2.1	0.017
Stance – involved (%GC)	61.2 ± 3.6	60.4 ± 1.9	0.296
Stance – uninvolved (%GC)	69.0 ± 5.9	60.5 ± 1.2	<0.001
Swing – involved (%GC)	38.8 ± 3.6	39.6 ± 1.9	0.296
Swing – uninvolved (%GC)	31.0 ± 5.9	39.5 ± 1.2	<0.001
SLS – involved (%GC)	31.1 ± 5.9	39.6 ± 1.2	<0.001
SLS – uninvolved (%GC)	38.8 ± 3.8	39.7 ± 1.9	0.272
DLS – involved (%GC)	30.1 ± 5.7	20.8 ± 2.9	<0.001
DLS – uninvolved (%GC)	30.3 ± 5.8	20.8 ± 2.9	<0.001

Table 1: Spatiotemporal characteristics of patients with SONK and healthy controls. Results are presented as mean ± SD.

Figure 1: Limb asymmetry in selected spatiotemporal gait parameters.
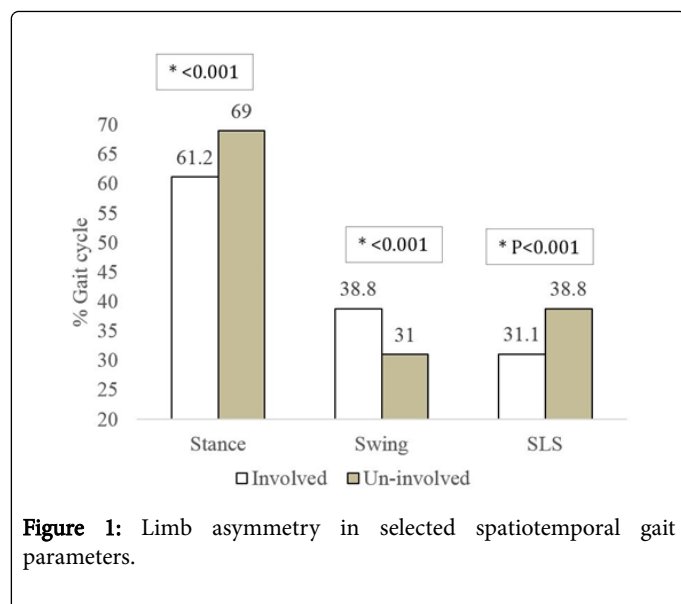
Discussion

There are varying theories on the etiology of knee osteonecrosis. The current perspective is that localized vascular insufficiency leads to necrosis of the subchondral bone with subsequent disruption of the nutrition supply to the cartilage above [24]. Others postulate that that pathology is secondary to subchondral fractures [25]. Another assumption postulate that altered biomechanics of the knee, which may cause an increased contact pressure, lead to the development of osteonecrosis [26].

Although gait analysis is a well-recognized method to assess biomechanical changes at the knee, there is no data on how SONK affects gait. This study aimed to characterize the changes in spatiotemporal gait patterns of patients with SONK compared to healthy controls. We found significant alterations in all gait parameters suggesting that gait is significantly compromised by the disease. This is not surprising, considering the fact that the knee joint is one of two weight-bearing joint that absorbs most of the loads while walking [27]. Previous studies have shown gait deviation in different knee pathologies including knee OA [28], anterior cruciate ligament tear [29], meniscal tear [13], anterior knee pain [30] and in patients post total knee arthroplasty [31]. Our results suggest that patients with SONK walk slower (-38%), with lower cadence (-46%) and shorter step length (-25%) compared to healthy controls. Furthermore, patients spend more time in DLS and reduce SLS from the involved knee. These alterations may be due to a new gait strategy adopted by the patients in order avoid joint loading and pain.

A diagnosis of SONK is done by MRI, usually after the patient report on the acute onset of medial-sided knee pain not precipitated by trauma. Outcome measures to assess the effect of treatment often include repeated MRI and use of self-reported pain levels [8,32]. These assessment tools have some limitations: MRI is an expensive test that requires a relative long waiting time, and self-reported pain assessment is a subjective one that should be supported with objective tools. Evaluating and understanding the gait alterations and compensations of patients with SONK may help in better assessing the severity of the condition and how it affects the patient's functional condition. It may also serve as an additional tool to assess the effect of different treatment modalities. However, this assumption should be validated in future studies.

The most prominent change was the reduction in single limb support of the affected knee. SLS reflects the ability of a knee joint to bear loads solely while the contralateral limb swings forwards. Normally, SLS values range between 38.5% and 40.5% of the gait cycle, however in patients with SONK this value decreased to 31.2%. The reduction in SLS indicates that the patients are unable\fear of weight bearing on the affected knee. Another important finding was the significant asymmetry between limbs in SLS. This should be addressed and monitored since limb asymmetry may have severe ramifications in the future.

A few limitations should be acknowledged. Firstly, this was a retrospective analysis of patients seeking treatment at a private clinic. As such, the study population may have been biased to those who were exposed to this clinic rather the entire population. We do not believe, however, that this had an effect on the results, and we believe the results of our study are good representatives of the examined population. Nevertheless, since this is the first time that gait assessment is reported on this population, future studies are needed to validate and expand the results. Secondly, significant differences in weight and BMI were found among patients with SONK and healthy controls. Ideally, homogeneous groups in terms of age, gender distribution, weight, height and BMI are warranted. We addressed this limitation with a statistical procedure that treated weight and BMI as covariates. Applying this method showed that the differences between groups still existed. This indicated that both weight and BMI has less effect on the differences found between groups. Thirdly, other factors, such as foot mechanics, might also affect the results. Foot deformities were not captured in this study, but patients with other lower extremity pathologies, including in the foot and ankle were excluded. Future studies should also consider monitoring foot deformities in patients with SONK and their affect o gait patterns.

Conclusions

We found significant alterations in all gait parameters in patients with SONK as compared to normal control and the non-injured limb suggesting that gait is significantly compromised by the disease.

Conflict of Interests:

AE, AM and RD hold shares in AposTherapy. No non-financial conflicts of interest exist for any of the authors

Authors' contributions

EA- Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; was involved in drafting the manuscript or revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

GS- Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; was involved in drafting the manuscript or revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that

questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

RD- Was involved in revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

OL- Was involved in revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

RD- Was involved in revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

BP- Was involved in revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

MF- Was involved in revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

AM- Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; was involved in drafting the manuscript or revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

AE- Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; was involved in drafting the manuscript or revising it critically for important intellectual content; gave final approval of the version to be published. Agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Trial registration:

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