Original Paper

Complexity of Gait Angle Measurements at the Ankle Joint During Midstance in Patients with Osteoarthritis

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ABSTRACT: The evolution of rehabilitation treatments can be quantified through goniometric measurements. Thus, a video goniometer, and an app-based goniometry program can be both useful and a reliable method of obtaining a data base through which we can see if a certain rehabilitation treatment works out for our patients and during times such as the Covid-19 pandemic, a telemedicine approach can be done. Midstance is a sub-moment of the gait pattern, important in the stability of the lower limb, but that can also direct us towards a patient prone to falls. Osteoarthritis is a disease that causes high disability because of the cellular degradation that also affects normal gait. Four groups of subjects: subjects suffering from hip osteoarthritis, knee osteoarthritis, hip and knee osteoarthritis and control group, have been filmed and recorded their midstance joint range of motion in the Angles App. The dominant limb has been proven to have a more extended ankle in the hip osteoarthritis group, compared to knee osteoarthritis, hip and knee osteoarthritis or control group. Females have presented a more extended ankle, wearing high heels for a long period of time can be the cause of that. Subjects with knee osteoarthritis have presented a more flexed ankle in the dominant limb compared to the ones suffering from hip and knee osteoarthritis or control group. The ankle joint can also have its range of motion measured with a video goniometer, helping us compare results in between sessions of rehabilitation in osteoarthritic patients.

KEYWORDS: *Goniometer, telemedicine, covid-19, video assessment, osteoarthritis.*

Introduction

Goniometry is the method through which we can quantify the evolution of one's rehabilitation steps throughout the years and in between sessions. The physician measures the range of motion (ROM) of each joint, uploads it in a data base and updates it constantly. Be that as it may, classic goniometry occupies a lot of time in one's practice, and also a lot of important details can be missed, but now, with the help of technology and the ubiquity of the phone one can have more than one option of measurement.

Three-dimensional motion analysis has its better purpose, being completed by plantar pressure plates, as well as electromyography (EMG) analysis [1-4], but because of the high prices and the necessity of a gait analysis lab [5], one can find more accessible options as a phone app, such as Angles Video Goniometer app [6], offered on the iOS software. Its validity and reliability has been proven compared to the mechanical goniometer as well as the Kinovea equipment (a software made for the two-dimensional analysis) [7].

A video goniometer has also been proven to come in handy lately as many facilities of rehabilitation have had their activity temporary suspended due to the Covid-19 pandemic, and telemedicine had to be performed in order for the patients to receive the best advice and rehabilitation steps [8-12]. Thus, a goniometer that can be handled just by filming the patient by a relative, in their home, without having to actually come in the facility, while moving uploading the video in the app and then measuring from afar can be the best tool for a physical therapist from now on, helping the physician to give objective pieces of advice until the possibility of a physical examination to be accomplished is given.

Gait has been considered to be a new and improved method of analysis and diagnosis in certain neurological and musculoskeletal diseases that come into the rehabilitation practices [13-15], but up until now there were insufficient data of the kinematic parameters to be taken into account as quantifiable measures so that hip and knee osteoarthritis could be diagnosed [1,16]. Midstance is the second sub-moment of gait, after loading response, followed by terminal stance, initial swing, midswing and terminal swing [15] and contains the first part of the single leg-support period and stability. Stability maintenance and the prevention of falling [17,18], especially of the elderly patients,

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is one of the most important objectives in rehabilitation.

Osteoarthritis is an evolutive disease consisting of lack of movement in the afflicted joints [19] causing impairment in more than 40 million people all over Europe [20] due to the extracellular degradation of the matrix, that comes as a result from injuries, either big or small occurring during one's lifetime.

This research paper focuses on the midstance moment of gait, measuring the alterations of the ankle joint that have happened due to the presence of OA changes in the above joints (knee and hip), revealing thus the importance of kinematic chains.

Materials and Methods

Participants

A single blinded randomized trial has been conducted throughout this paper. A written informed consent has been given by all the patients that have participated voluntarily and the principles outlined in the Declaration of Helsinki have been fully respected. The study has been approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova. From the initial 154 patients with the right dominant limb that have offered to take a part of our research, twelve have been excluded since the criteria of being able to walk without a cane or a walking frame was not met, their OA being too advanced (Figure 1).

In addition, six more patients were also presenting sever neurological lesions, after stroke, along with OA. The remaining 136 subjects were divided into four groups of people with the age limits: 42-83 years old: subjects with the diagnosis of hip OA, knee OA, hip and knee OA and control group.

Statistical Analysis

This observational study has had standardized methods used for the comparison made between the groups, using the one-way ANOVA test. A personal computer containing a statistics package software has been used (GraphPad Software, Prism 9.0 for macOS). The statistical significance was set at $p<0.05$. Data for statistical analysis were calculated as means±95% Cis.

The subjects were asked to walk for a few times before their gait was recorded, at a normal speed. With the same normal speed, the patient was video recorded 3 times on each side (with 6 recordings per patient), having the camera fixed 1m above the ground on a tripod, offering stability of the video examination and the opportunity of studying the whole body movement in the sagittal plane. After the recording, the videos were uploaded on the Angles video goniometry app, giving us the opportunity to measure the range of motion of hip, knee and ankle in both midswing and midstance. This particular research paper will only present the data gathered by the alterations in the ankle joint due to OA during midstance.

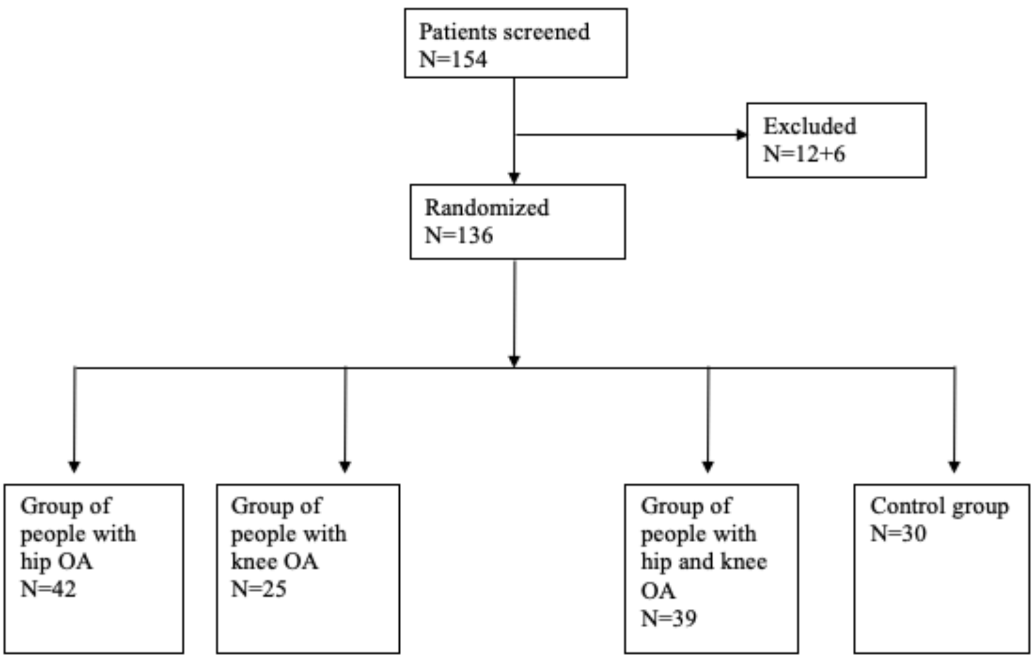

Figure 1. Flowchart of how the participants of the study have been assigned.

Results

In table 1, the statistically significant data shows the changes between the dominant and non-dominant limbs of the groups (Figure 2) and the fact that the subjects suffering from hip OA have a more extended ankle (the plantar flexion is higher) on the dominant limb than the left side (non-dominant limb) with a mean difference of 10.17 degrees. Also, the group suffering from HOA, presents a more extended ankle than the group suffering of KOA, on the right side, with a difference of 7.002 degrees, than the right ankle of the group suffering of hip and knee OA with a 10.29 degrees difference and then the right ankle of the control group with a 12.02 degrees difference. On the non-dominant side, the subjects with HOA also have a more extended ankle than the ones with KOA with a mean of 7.815 degrees.

The patients with knee OA on the dominant side have a 10.98 degrees more extended ankle than the ankle on the non-dominant side.

On the non-dominant side as well, the subjects with knee OA have a more flexed ankle, with a mean difference of-8.593 than the people suffering from hip and knee OA, and also thank the control group with a mean difference of-10.44.

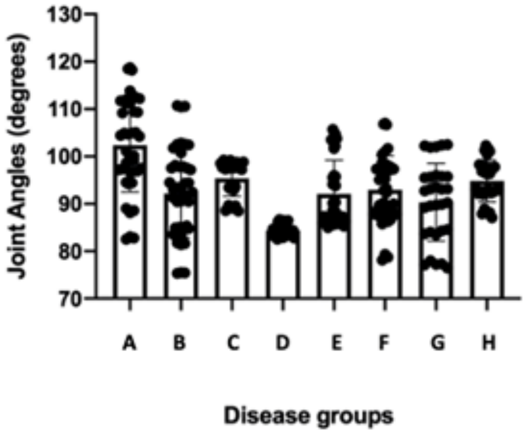

Figure 2. Measurements of the ankle's ROM during midstance. Changes between disease groups. Left vs. Right. Normal gait speed.

A-Group with hip osteoarthritis-right ankle; B-Group with hip osteoarthritis-left ankle; C-Group with knee osteoarthritis-right ankle; D-Group with knee osteoarthritis-left ankle; E-Group with hip and knee osteoarthritis-right ankle; F-Group with hip and knee osteoarthritis-left ankle; G-Control group-right ankle; H-Control group-left ankle.

Table 1. Ankle joint angle range of motion during midstance. Changes between the left and right side of the measured subjects. Normal gait speed.

Šídák's multiple comparisons test	Mean Diff	95,00% CI of diff	Adjusted P value
Group of patients with hip osteoarthritis-right ankle vs. Group of patients with hip osteoarthritis-left ankle	10,17	5,391 to 14,94	<0,0001
Group of patients with hip osteoarthritis-right ankle vs. Group of patients with knee osteoarthritis-right ankle	7,002	1,474 to 12,53	0,0032
Group of patients with hip osteoarthritis-right ankle vs. Group of patients with hip and knee osteoarthritis-right ankle	10,29	5,424 to 15,16	<0,0001
Group with of patients hip osteoarthritis-right ankle vs. Control group-right ankle	12,02	6,793 to 17,25	<0,0001
Group with of patients hip osteoarthritis-left ankle vs. Group of patients with knee osteoarthritis-left ankle	7,815	2,287 to 13,34	0,0006
Group of patients with knee osteoarthritis-right ankle vs. Group of patients with knee osteoarthritis-left ankle	10,98	4,791 to 17,17	<0,0001
Group of patients with knee osteoarthritis-left ankle vs. Group of patients with hip and knee osteoarthritis-left ankle	-8,593	-14,20 to -2,987	0,0001
Group of patients with knee osteoarthritis-left ankle vs. Control group-left ankle	-10,44	-16,37 to-4,515	<0,0001

In table 2, the differences between female subject groups (Figure 2 (Groups A-H)) are as such: females suffering from HOA have a more extended right ankle (dominant limb) than the females suffering from hip and knee OA with a mean difference of 9.271 degrees and then the control group with a mean difference of 16.92 degrees.

On the non-dominant side, the same ankle extension of the subjects with HOA can be noticed in comparison to the KOA group with a mean difference of 12.89 degrees and to the

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subjects suffering from hip and knee OA with a mean difference of 5.067.

The patients with KOA on the dominant side have a 11.27 degrees more extended ankle than the ankle on the non-dominant side. On the left side, the ankle is more extended at the patients with KOA than the ones with hip and knee OA with-7.828 degrees and then the control group with-11.14.

Also, the patients with KOA on the dominant side have a more extended ankle than the control group with a difference of 12.22 degrees.

The subjects with hip and knee OA have a more extended dominant ankle than the ones from the control group with a 7.649 degrees mean difference.

The female control group has a more flexed ankle on the dominant side than the non-dominant side (left) with a mean of-12.1 degrees.

Table 2. Ankle joint angles during midstance.
Changes between right and left side of the female groups. Normal gait speed.

Šídák's multiple comparisons test	Mean Diff	95,00% CI of diff	Adjusted P Value
Group of patients with hip osteoarthritis-right ankle vs. Group with hip and knee osteoarthritis-right ankle	9,271	4,285 to 14,26	<0,0001
Group of patients with hip osteoarthritis-right ankle vs. Control group-right ankle	16,92	10,93 to 22,91	<0,0001
Group of patients with hip osteoarthritis-left ankle vs. Group of patients with knee osteoarthritis-left ankle	12,89	7,383 to 18,41	<0,0001
Group of patients with hip osteoarthritis-left ankle vs. Group of patients with hip and knee osteoarthritis-left ankle	5,067	0,08081 to 10,05	0,0431
Group of patients with knee osteoarthritis-right ankle vs. Group of patients with knee osteoarthritis-left ankle	11,27	5,508 to 17,02	<0,0001
Group of patients with knee osteoarthritis-right ankle vs. Control group-right ankle	12,22	6,003 to 18,44	<0,0001
Group of patients with knee osteoarthritis-left ankle vs. Group of patients with hip and knee osteoarthritis-left ankle	-7,828	-13,08 to -2,573	0,0002
Group of patients with knee osteoarthritis-left ankle vs. Control group-left ankle	-11,14	-17,36 to -4,922	<0,0001
Group of patients with hip and knee osteoarthritis-right ankle vs. Control group-right ankle	7,649	1,892 to 13,41	0,0016
Control group-right ankle vs. Control group-left ankle	-12,1	-18,74 to -5,449	<0,0001

Table 3 and Figure 3 (Groups I-P) emphasizes the differences between the male groups of subjects as following: subjects with HOA have a more flexed ankle on the dominant side, with-14.35 degrees comparing to the non-dominant side, a more extended ankle joint on the left side than the ones suffering of KOA on the non-dominant (left) side with a mean difference of 25.38 degrees, a more extended left ankle than the group with hip and knee OA with a mean difference of 14.08 and also a more extended left ankle than the control group on the non-dominant side with a 14.93 degrees difference.

Subjects with KOA present the non-dominant ankle-11.3 degrees more flexed than the ones with hip and knee OA and-10.46 degrees more flexed than the control group.

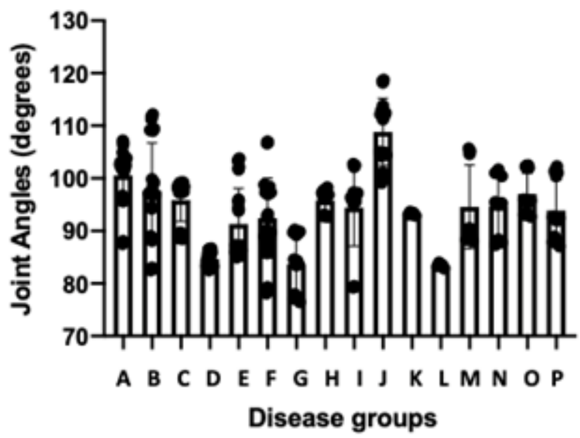

Figure 3. Joint angles ROM measurements of the ankle during midstance. Changes between disease groups. Male. Female. Normal gait speed.

A-Group with hip osteoarthritis-right ankle-female group; B-Group with hip osteoarthritis-left ankle-female group; C-Group with knee osteoarthritis-right ankle-female group; D-Group with knee osteoarthritis-left ankle-female group; E-Group with hip and knee osteoarthritis-right ankle-female group; F-Group with hip and knee osteoarthritis-left ankle-female group; G-Control group-right ankle-female group; H-Control group-left ankle-female group; I-Group with hip osteoarthritis-right ankle-male group; J-Group with hip osteoarthritis-left ankle-male group; K-Group with knee osteoarthritis-right ankle-male group; L-Group with knee osteoarthritis-left ankle-male group; M-Group with hip and knee osteoarthritis-right ankle-male group; N-Group with hip and knee osteoarthritis-left ankle-male group; O-Control group-right ankle-male group; P-Control group-left ankle-male group.

Table 3. Ankle joint angles during midstance.
Changes between right and left side of the male groups. Normal gait speed.

Šídák's multiple comparisons test	Mean Diff	95,00% CI of diff	Adjusted P value
Group of patients with hip osteoarthritis-right ankle vs. Group of patients with hip osteoarthritis-left ankle	-14,35	-20,42 to-8,285	<0,0001
Group of patients with hip osteoarthritis-left ankle vs. Group of patients with knee osteoarthritis-left ankle	25,38	16,18 to 34,59	<0,0001
Group of patients with hip osteoarthritis-left ankle vs. Group of patients with hip and knee osteoarthritis-left ankle	14,08	6,647 to 21,51	<0,0001
Group of patients with hip osteoarthritis-left ankle vs. Control group-left ankle	14,93	8,561 to 21,29	<0,0001
Group of patients with knee osteoarthritis-left ankle vs. Group of patients with hip and knee osteoarthritis-left ankle	-11,3	-21,46 to -1,149	0,0168
Group of patients with knee osteoarthritis-left ankle vs. Control group-left ankle	-10,46	-19,86 to -1,055	0,0169

All the other data were not statistically significant.

Discussions

During normal midstance the lower limb that is moving towards forming the next step of the gait has a flexed hip that starts its extension due to the contraction of the gluteus medius, a flexed knee and a dorsiflexed ankle, that begins the extension (plantar flexion) due to the contraction of the triceps sural muscle integrated in the lower limb extension chain [21,22].

In osteoarthritic patients though, especially the ones suffering from HOA, on the dominant limb, due to Trendelenburg sign [23-25], most of them have presented in this study a more extended ankle compared to the non-dominant limb, and also, in patients with HOA, compared to the ones suffering from KOA, hip and knee OA or the control group. Comparable results have been proven in hip strengths deficits as a risk factor in people suffering from often ankle sprains [26-28].

In patients suffering from KOA, a more flexed ankle of the non-dominant limb was discovered, compared to the dominant one, to the patients with hip and knee OA or to the control group. This can be explained through the triple flexion kinematic chain, since the knee is in its maximum flexion moment via the hamstring muscles, and the ankle starts to be more extended.

In the female group of patients suffering from HOA on the dominant and non-dominant limb, a more extended ankle was noticed. An explanation for this can be the fact that within the male group of patients there were none suffering from ballerina syndrome, thus, the high heel wearing can be a cause of the different muscle usage between male and female patients. Wearing high heels can be one of the main reasons of why the female joint is more extended compared to the control group, also taking into the account the more flexed ankle in the male patients with knee OA [29].

It has been proven that ankle instability [30] can affect the other joints as well, thus, the deficit of posture control [31] or the motion altered while developing functional tasks [32,33] can be prevented with a thorough diagnostic. One has to keep in mind the fact that a limited ROM of the lower limb joints can turn into a high disability due to increased joint rigidity [34].

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Conclusion

To conclude, the ankle joint can be complex beyond its anatomy and biomechanics. During midstance, between the group of patients suffering from HOA, KOA, hip and knee OA, we can notice more and more similarities and differences due to other factors.

Thus, one cannot take into the account just the syndromes for which a patient presents him or herself into our practice, but the evaluation must be done thoroughly. In this way, the new phone apps can also help us see the evolution from the first treatment and compare it to the next one, even during a telemedicine evaluation, and also helping the patients see their own progress.

Abbreviations

OA-osteoarthritis; KOA-knee osteoarthritis; HOA-hip osteoarthritis; ROM-range of motion.

Conflict of interests

None to declare.

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