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GAIT ANALYSIS USING PHYSICAL EXAMINATION AND DIGITAL TECHNIQUES

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Summary: Gait examination is an important component of the patient assessment prior to movement therapy. With the advancement of video technology and computer science, digital analysis of gait has become possible. This research aims to physically examine gait and analyze video recordings using dedicated software. A voluntary group of 10 individuals diagnosed with coxarthrosis or gonarthrosis constituted the study group, while the control group comprised 10 individuals without lower limb musculoskeletal disorders. The mean age of the study group was 57 ±4.03 years, and the mean age of the control group was 54.2 ±3.16 years. The research involved conducting physical examinations of gait and recording walking sessions with body markers. The software facilitated the presentation of marker displacements on diagrams in both vertical and horizontal planes. Visual analysis and a two-sample t-test were employed. The physical musculoskeletal examination successfully identified causes of claudication. Significant differences were observed between the two groups across all kinematic gait indicators. The mean stance width in the test group was 17.65 ±3.09 cm, while the control group averaged 8.75 ±1.23 cm ($p < 0.001$). The walking speed, assessed using a two-sample t-test, also yielded a significant difference ($p < 0.001$). Key diagrams representing the groups during functional analysis were presented. Visual analysis revealed distinct variations in marker frequency and vertical and horizontal displacements between the groups. The study group exhibited notable deviations in the displacement diagrams on the affected side of the body. The average of the maximum and minimum points on the charts demonstrated a significant difference between the groups in terms of body displacement. The identified differences in gait between the two groups align with the results of the physical examination. The graphical representation of disparities in body displacement between the two halves of the body in the study group indicates the future potential of digital gait analysis for practical applications and monitoring the effectiveness of physiotherapy.

Keywords: *gait, physical examination, digital gait analysis*

INTRODUCTION

Walking is a natural element of self-sufficiency, work, and integration into society. Therefore, it is a major factor influencing the quality of life. It is no coincidence that the long-term goal of medical rehabilitation often revolves around harmonizing gait, with movement therapy playing a significant role. Prior to commencing therapy, physiotherapists conduct a patient examination, with special attention given to the examination of walking in cases of gait disturbances. This examination includes musculoskeletal assessment of the lower limb [1, 2], observation of gait and its phases [3, 4, 5], and examination of gait kinematic indicators through measurements [6].

In today's world, the combination of video technology and computer technology allows for the graphical visualization of gait [6, 7, 8]. Although there are several examples of research in the literature, most of them require laboratory conditions and are prohibitively expensive [9, 10].

The objective of this research is to illustrate the differences between harmonious gait and limping by examining the displacement of the shoulder girdle and pelvis. This examination will be conducted through physical examination of gait and the graphic representation obtained from video recordings.

Regarding the research, the following questions have arisen:

- What are the musculoskeletal examination findings and gait kinematic indicators in the examined group, with a focus on identifying the most common causes of gait changes, such as limb length discrepancy and load-induced pain?
- Are there significant differences in gait kinematic characteristics between the test group and the control group?
- Do the graphs obtained from software analysis show differences in vertical and horizontal displacement between the two groups?
- Can "distortion" or deviance be observed in the diagrams of individuals within the studied group?
- Is there a significant difference between the two groups in terms of the average median values of maximum and minimum deflection points in the vertical and horizontal displacement charts?

MATERIAL AND METHODS

The study was conducted in 2022, and it was carried out within the participants' homes. The individuals willingly participated in the research due to their interest in the research topic. Inclusion criteria required participants to be between the ages of 50 and 65. Additionally, for the study group consisting of 10 individuals, a further criterion was a diagnosis of hip or knee arthrosis. The control group, consisting of 10 individuals matched for age and gender, had to be free of lower limb complaints and diagnosed musculoskeletal disorders.

The research objective was centered around developmental research. Musculoskeletal physical examinations of the sample members were conducted, with a specific focus on gait analysis. Subsequently, participants' walking patterns were recorded using a smartphone camera from a rear perspective. Four distinct markers were affixed to the participants' bodies: two on the spina scapulae and two on the spina iliaca posterior superiores.

Specialized software developed for this study facilitated the analysis of marker displacement by generating diagrams. These diagrams depicted the vertical and horizontal displacements of the markers during walking, enabling individual analysis for each participant.

By comparing the graphs generated for the control group and the study group, differences between the two groups and disparities in marker displacement within the test group's body halves were observed. Statistical analysis involved employing a two-sample t-test to investigate the differences between the two groups based on the obtained variables. The significance level for the statistical test was set at $p \leq 0.05$.

RESULTS

The findings from the musculoskeletal examination are presented in *Table 1*, depicting the identified causes responsible for alterations in gait. Among the study participants, the predominant cause observed was loading pain, reported by all individuals within the study cohort. The average pain intensity, assessed using the Visual Analog Scale, was recorded as 4.17 and 6. Additionally, a limb length discrepancy exceeding 1 cm was found to impact five individuals in the study group. Notably, limitations in the range of motion were measurable, particularly in hip extension and knee extension. However, despite a slight decrease in muscle strength, there was no significant impact observed on gait or its various phases.

Table 1
Results of the physical musculoskeletal examination (n = 20)

Examination	Study group		Controll group (n=10)
	Coxarthrosis (n=5)	Gonarthrosis (n=5)	
Lower limb deformity (participants)	2	3	-
Relative limb length difference (participants)	1	1	0
Absolute limb length difference (participants)	2	1	0
Thigh circumference difference average (cm)	1.5 ±0.58	1.6 ±0.89	1.67 ±1.15
Calf circumference difference average (cm)	1.5 ±0.71	1	1 ±0
Restricted joint mobility (participants) hip:knee:ankle	5:0:0	0:4:0	0:0:0
Loss of muscle strength (participants)	4	4	0
Pain VAS scale average	4.17 ±2.7	6 ±2	0

Table 2 displays the kinematic indicators of gait for both groups. There was a significant difference observed in each indicator between the study group and the control group.

Table 2

Results of kinematic parameters of walking (n = 20)

Kinematic indicators	Study group	Controll group	p-value
Average step distance (cm)	83.2 ±4.85	97.4 ±11.64	**0.020**
Average walking width (cm)	17.65 ±3.09	8.75 ±1.23	**<0.001**
Average of the total step cycle length (cm)	155.4 ±11.96	171.8 ±14.63	**0.007**
Average number of steps per minute (step/minute)	92.90 ±8.52	105.1 ±6.44	**<0.001**
Average walking speed (m/s)	1.29 ±0.14	1.70 ±0.22	**<0.001**

To demonstrate digital analysis, one person was selected from each of the control group and the study group as representatives. *Figures 1*, *2*, and *3* depict the vertical displacement of markers placed on the spina scapulae. In *Figure 1*, which represents the control group, the curves overlap approximately, and the curve exhibits a typically high frequency.

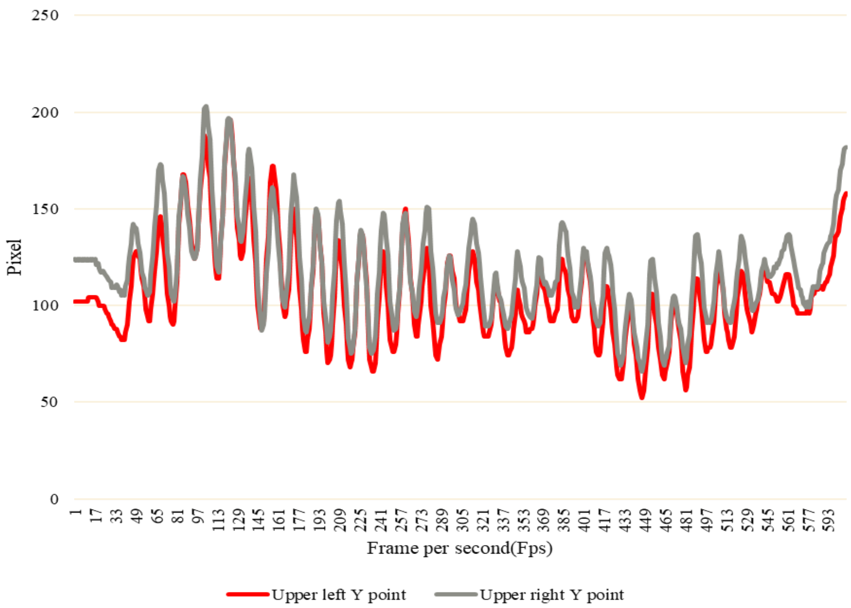

Figure 1. *Upper right and left point Y axis movement (n = 1)*

Figures 2 and *3* illustrate the graphs of a patient with right-sided coxarthrosis from the study group, showing the displacement of the upper right and upper left markers. It is evident that the frequency is lower, and the diagrams of the two sides do not overlap. On the figure representing the right side, there is a periodic M-shaped distortion or deviation that appears. This discrepancy is attributed to the difference in the number of steps per minute, and the deviation emerges as a compensatory movement during the subphase of rolling.

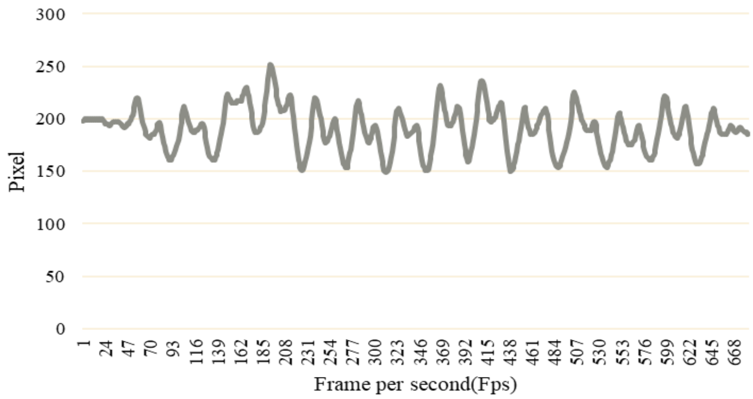

Figure 2. *Upper right Y axis movement (n = 1)*

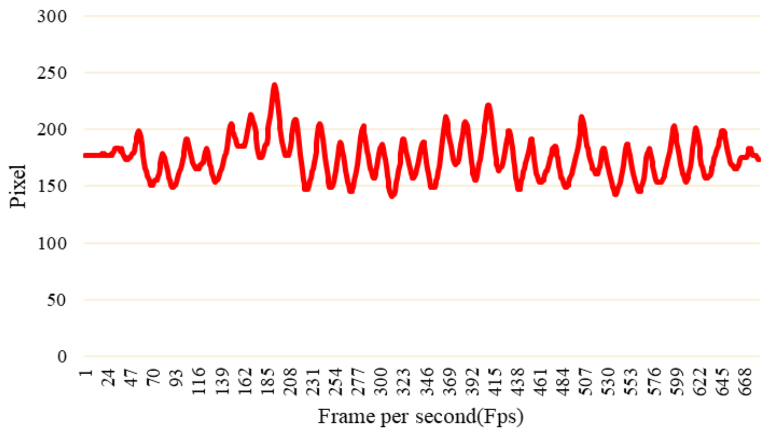

Figure 3. *Upper left Y axis movement (n = 1)*

The two figures presented depict the vertical displacement of markers positioned on the spina iliaca posterior superiors. In both groups, there is an overlap in vertical displacements, although the studied group exhibits a lower frequency. This discrepancy can be attributed to the disparity in steps per minute between the two groups.

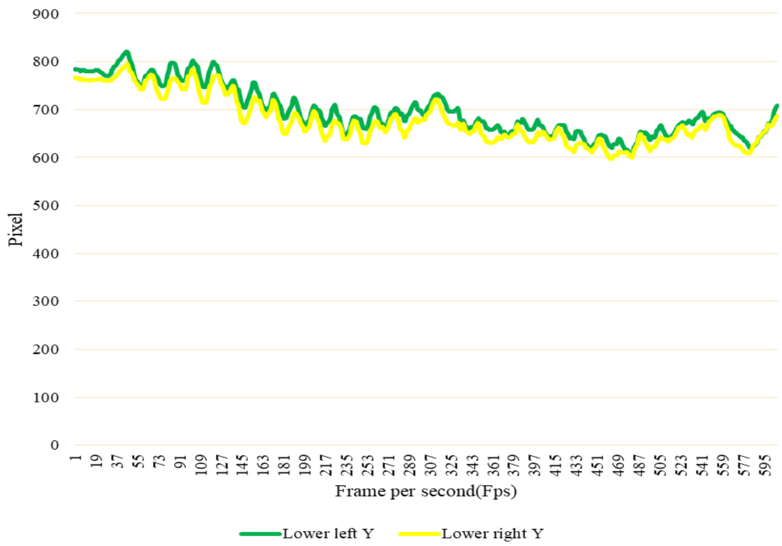

Figure 4. *Lower left and right point Y axis movement (n = 1)*

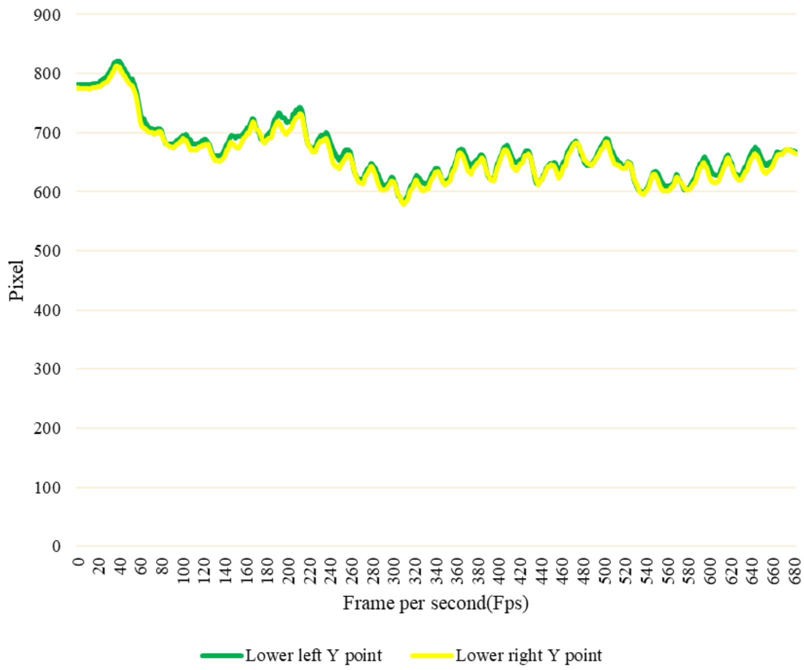

Figure 5. *Lower right and left Y axis movement (n=1)*

The following two figures depict the movements that take place in the horizontal plane. *Figure 6* illustrates the symmetry observed in the control group's figures. On the other hand, *Figure 7* showcases the group under examination, exhibiting significantly larger lateral deflection and symmetrical oscillations, which are associated with limping.

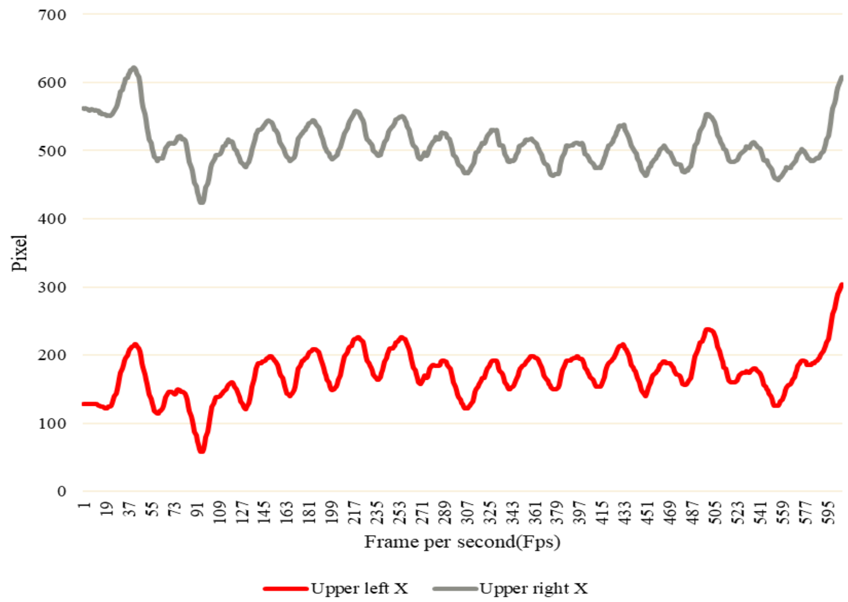

Figure 6. *Upper left and right point X axis movement (n = 1)*

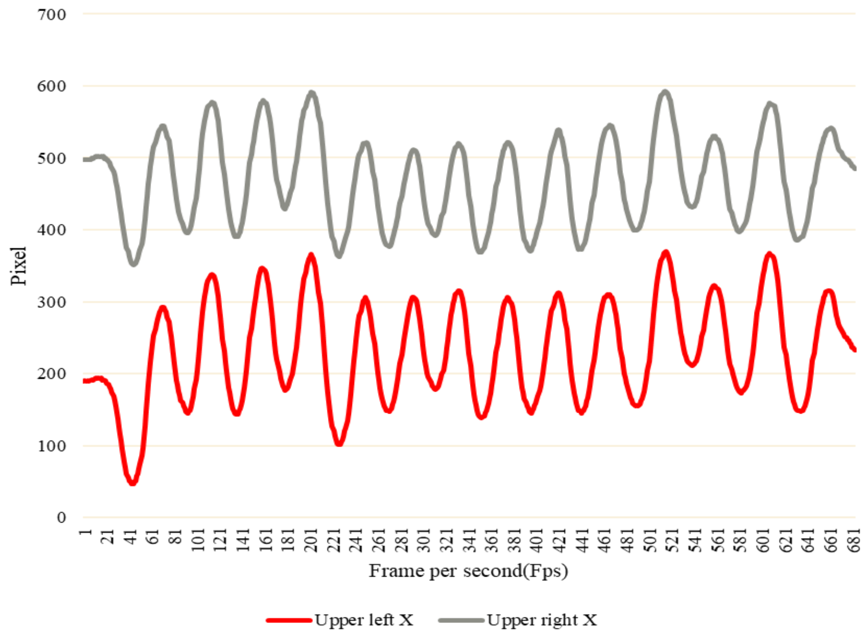

Figure 7. *Upper left and right point X axis movement (n = 1)*

The authors observed similar effects in the horizontal movements of lower marker points. According to *Figure 8*, the deflection is smaller for the control group, whereas it is significantly larger for the test group. In both cases, the displacement of the two pelvic halves is symmetrical.

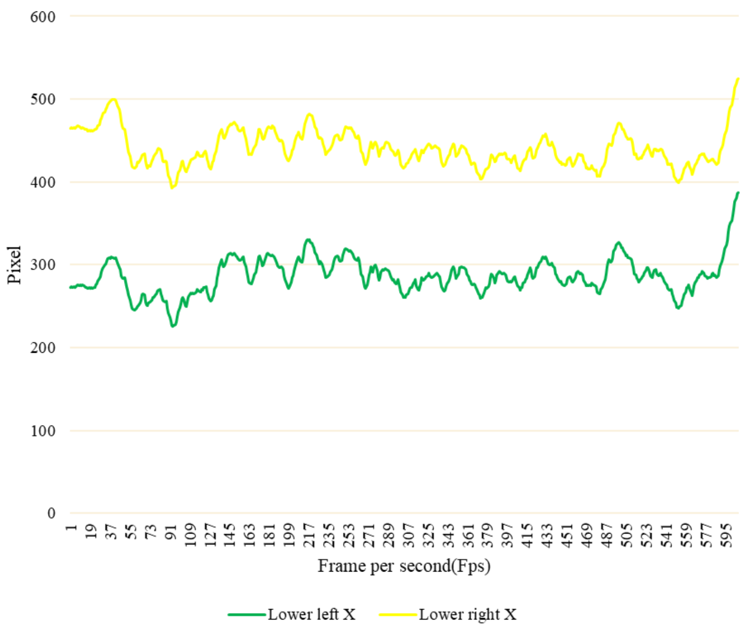

Figure 8. *Lower left and right point X axis movement (n = 1)*

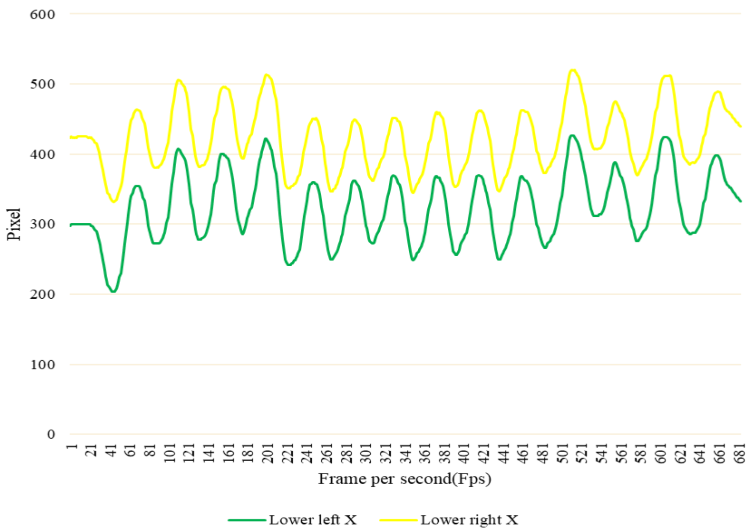

Figure 9. *Lower left and right point X axis movement (n = 1)*

In the charts of both groups, the maximum and minimum points of vertical and horizontal displacements are indicated. The median values were then calculated from the wing values. Subsequently, the average of these median values was separately examined for the two halves of the body, as shown in *Table 3*. It can be observed that the obtained data differ vertically and horizontally between the two groups. In the test group, the displacement difference between the two halves is greater compared to the control group. The difference is significant, with the exception of one case.

Table 3

Averages of the differences between the medians of the maximum and minimum scores of the two sides of the examinated and control groups (n = 20)

Marker displacements on the axes	Study group	Controll group	p-value
Displacement of upper markers on vertical axis	6±1.25	3.7±1.70	**0.030**
Displacement of lower markers on the vertical axis	8.3±3.92	4.6±3.17	**0.032**
Displacement of upper markers on the horizontal axis	13±6.62	7.5±4.2	**0.040**
Displacement of lower markers on the horizontal axis	4±4.22	3±2.45	0.525

DISCUSSION

Searching for answers to the questions of the research, we found the following. The background of limping in the examined group is primarily pain caused by loads, limb length difference and lack of complete extension. There is a significant difference in all kinematic indicators of gait of the two groups. The gait charts of the two groups show differences in both vertical and horizontal displacement. On the *Figure 2* of the group study, showing vertical displacement, a clear deviance (distortion) is observed. By comparing the test group and the control group, the difference in displacement between the two halves of the body can be confirmed by variables. The physical musculoskeletal examination requires great experience and practice. It can help to visualize movements during walking with the help of computer technology. The potential of smartphones is worth exploiting. With easy-to-implement video recording and the application of a future downloadable application can be realized to analyze the gait on diagrams. The resulting curves could support the results of the musculoskeletal physical examination. They can help track the effectiveness of physiotherapy. The differences in displacement, the decrease or elimination of deviance in size on the diagrams do not only give positive feedback to the physiotherapist about the improvement of gait. It can motivate the patient, strengthen his faith in healing.

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