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INTER-EXAMINER, WITHIN-SESSION AND BETWEEN-SESSION REPEATABILITY OF KINEMATIC GAIT PARAMETERS AMONG ADULT SUBJECTS

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ABSTRACT

Purpose. This research aimed to assess the repeatability of results obtained when analysing gait by means of a system designed for objective gait analysis in a single laboratory setting by a single examiner within-session and between-sessions. **Methods.** For the purpose of this research, the BTS Smart-D movement analysis system, produced by Capture Motion System of Italy, was used. Four healthy adults were examined. The subjects took part in three gait analysis testing sessions, with each session separated by a two-day break. During each session, two sets of measurements were taken for each subject. Statistical analysis was performed with StatSoft's Statistica 7.1 software. **Results.** Within each session, all examined temporal and spatial parameters were found to be repeatable. Only in hip and knee joint rotation was repeatability not confirmed within session. Between the sessions, repeatability was confirmed in pelvic rotation, abduction/adduction of the knee joint and for all foot kinematic parameters. **Conclusions.** Conducting gait analysis by one researcher does not guarantee obtaining repeatable results for all measured kinematic parameters, either within one session or between sessions; caution ought to be exercised when interpreting results. Among the studied parameters, hip and knee joint rotation provided the most difficulty in obtaining repeatable results. For this reason, diagnostic and therapeutic decisions based on such data require the utmost consideration.

Key words: gait analysis, repeatability, kinematics

Introduction

Three-dimensional gait analysis is commonly applied in clinical practice and research conducted by biomechanics, kinesiologists, physiotherapists and physicians [1]. Comparison of a patient's gait analysis with normative values provides a basis for important decisions concerning treatment and allows for the assessment of surgical or therapeutical intervention. The interpretation of results, however, requires carefulness and the ability to discriminate between significant conclusions and artifacts or errors stemming from different sources. Therefore, the repeatability and reliability of research results is crucial aspect. In addition, another issue stems from the ability to properly interpret data [1–3]. Ignoring the sources of errors can lead to overinterpretating or overlooking important information [1, 2].

As far as the authors' knowledge is concerned, not one of the centres in Poland conducting gait analysis has published any results on the repeatability and reliability of such research. This is regrettable as reliable research, the results obtained and scientific evidence is the basis for effective and safe clinical practice, thus forming the main pillar of Evidence Based Medicine (EBM) [4].

Generally, the sources of errors in gait analysis can be internal and external (experimental). Some specific sources of experimental errors have been well analysed and cognized [1, 2, 5, 6]. The main factor determining the variability of results is believed to be the incorrect placement of markers on the subject's body [1–3, 7].

Despite the growing number of laboratories analysing gait, there is a shortage of consistent data concerning the repeatability and reliability of gait kinematics [1]. Therefore, each centre engaged in gait analysis should perform research on the repeatability level of their conducted measurements in groups of both healthy subjects and patients, with the aim of determining the quality of the collected data and its interpretation and, possibly, correcting any faulty research procedures. The main assumption for this would be towards obtaining repeatable results for the same patient in several sessions, regardless of the individual conducting the examination.

Therefore, this study aimed to assess the repeatability of gait analysis results obtained by means of a system for objective gait analysis in a single laboratory setting by a single examiner within session and between sessions.

Material and methods

This study was conducted at the Centre of Body Posture at the Józef Rusiecki University College in Olsztyn. For the purpose of providing objective gait analysis, the BTS Smart-D movement analysis system (Capture Motion System, Italy) was used. The system uses measurement markers that record movement by six infra-red

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Table 1. Anthropometric characteristics of test subjects

Variable	m	SD
Age (years)	22.3	1.1
Height (cm)	178.3	8.3
Weight (kg)	75.0	1.3
BMI	23.5	1.3

cameras. The markers were placed on the participants according to Davis [8] (Fig. 1). Data on the markers' displacement were collected at a sample frequency of 100 Hz.

Four healthy adults were randomly chosen for this examination; their anthropometric characteristics [mean values (m) and the standard deviation (SD)] are presented in Table 1. The subjects took part in three sessions, with each session separated by a two-day period. The anthropometrical measurements of the subjects were collected once, during the first session. In each session, the markers were placed on the subjects' bodies and then two sets of measurements were taken, with the testing procedure shown in Figure 2. All measurements were taken by only one examiner, who was trained by the BTS Smart-D's manufacturer and had one-years' experience in gait analysis.

Within each measurement, ten gait samples were recorded. Out of these, five samples were randomly chosen (Fig. 2) for later analysis. Gait cycle (GC) was determined for both lower limbs by means of foot-switches. For statistical analysis, the angle value of the range of pelvic movements and of the lower limbs was adopted in the frontal, sagittal and transverse plane at 51% of the gait cycle [2, 3], which corresponds to the beginning of the double support phase. The reliability of the kinematic gait parameters was reported for only one side (left), as according to Steinwender et al. [9] the reliability of kinematic parameters between the right and left legs is not significantly different. For each gait cycle, the temporal and spatial parameters were calculated, out of which the following were chosen for analysis: the percentage share of stance phase, swing phase and the double support phase during the gait cycle; cadence (number of steps per minute) and average velocity.

During each measurement set, there were on average 240 gait cycles collected, out of which 120 (based on the random selection of five out of ten recorded gait cycles) were subjected to detailed analysis. The mean values as well as standard deviations (SD) were calculated for each kinematic parameter, separately for each measurement and each session. In order to assess the significance in the differentiation between the two measurements (measurement I and measurement II) taken during one session (on three separate occasions), 20 gait cycles from each measurement were collected (five gait cycles for each of the four subjects). With the aim of assessing the differentiation level among all three sessions, 40 gait cycles were collected from each session

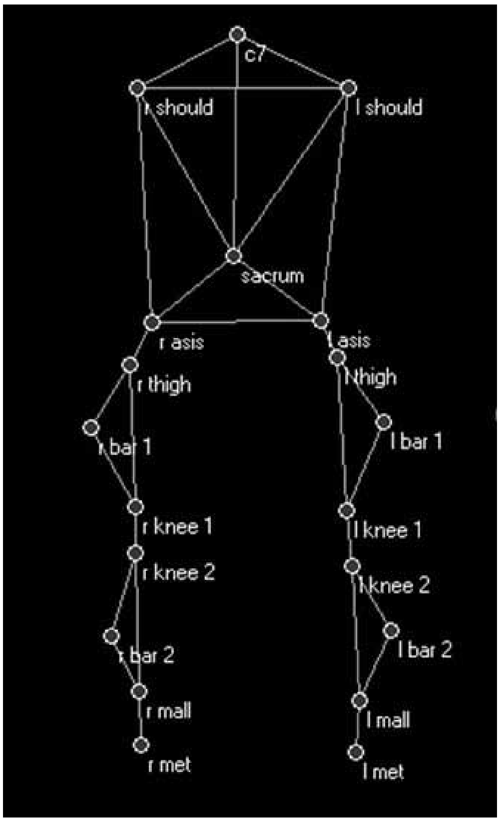

Figure 1. Marker placement points (Davis model)

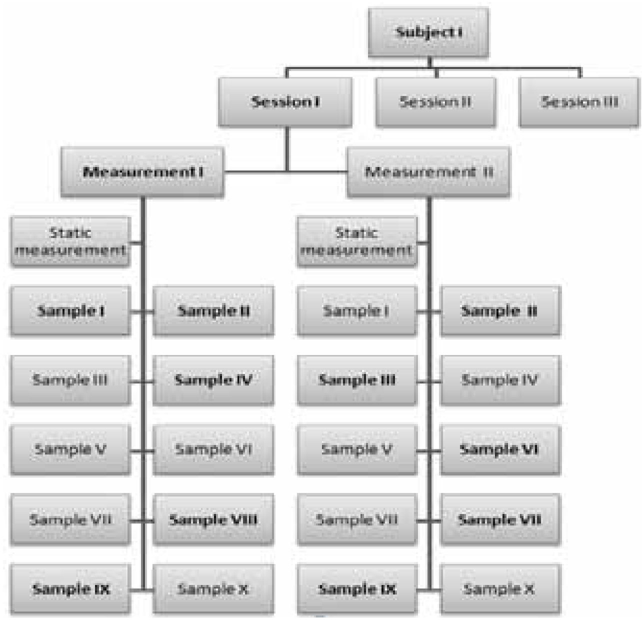

Figure 2. Testing procedure

(five gait cycles for each of the four subjects, from two measurements).

Although it was felt that the repeatability of the results between sessions, when two measurements are taken on the same day, could be assessed with the sample of collected measurements, the nature of clinical practice frequently allows only one measurement to be taken for a patient. Therefore, additional analysis on the results' repeatability was conducted with the first measurements from each session. For this purpose, 20 gait cycles from each of the first measurement were collected (five gait cycles for each of the four individuals).

Statistical analysis was performed using Statistica 7.1 (StatSoft, Poland). The Shapiro-Wilk test was used to assess the compatibility of the variables distribution and for normal distribution. The Wilcoxon test was used to assess the difference between the variables within one session, and the Friedman test was applied when analysing all three sessions. Statistical significance was set at $p > 0.05$. As repeatability was defined as the compatibility of subsequent measurements made of the same variable, conducted by the same researcher in a similar setting in similar conditions with the same methods and the same appliances [10], repeatable results were identified as results that do not differ significantly within session and between sessions ($p > 0.05$).

Results

For the analysed parameters, the inter-session results were found to be repeatable (Tab. 2). Within session, repeatability was not confirmed only for hip and knee joint rotation. The remaining kinematic parameters for the pelvis and lower limb were found to be repeatable within session (Tab. 2).

Among the temporal and spatial parameters, repeatability was not observed only in gait velocity ($p = 0.031$). Excluding the second set of measures taken during each session (whereby only the first measures were analysed), analysis showed that there are no statistically significant differences between the sessions ($p > 0.05$). For the remaining temporal and spatial parameters, the results were also found to be repeatable (Tab. 3).

Between sessions, repeatable results were obtained for pelvic rotation, adduction/abduction of knee joint, dorsal/plantar foot flexion and foot progression ($p > 0.05$). Repeatable results between sessions were not obtained for pelvic movements in the frontal and sagittal plane, hip joint rotation and movements of the knee joint in the sagittal and transverse cross-sections. Repeatable results between sessions were observed for the adduction/abduction of the hip joint, where two measurements were taken (40 cycles). Excluding from analysis the second set of measurements taken during each session (20 cycles), the first measurements were found not to be repeatable ($p = 0.043$). In the case of flexion and extension of the hip joint, no significant differences between the first measurements in each session were observed ($p > 0.05$). However, statistically significant differences between the sessions were observed based on both measurements taken in each session (Tab. 3).

Discussion

The results attained in this study are partially consistent with data from other gait studies. Repeatable results within one session were obtained between measurements for all examined spatial and temporal as well as for most of the measured kinematic parameters. Only

Table 2. Repeatability of measurements taken by the same examiner within each session (4 × 5 cycles)

	Session I		Session II		Session III	
	measurement I	measurement II	measurement I	measurement II	measurement I	measurement II
Stance phase (%)	59.7 (1.5)	59.9 (1.4)	59.5 (1.0)	59.7 (1.3)	60.2 (0.9)	60.3 (0.8)
Swing phase (%)	40.3 (1.5)	40.1 (1.4)	40.5 (1.0)	40.3 (1.3)	38.8 (0.9)	39.7 (0.8)
Double support phase (%)	9.7 (0.7)	9.5 (0.9)	9.1 (1.0)	9.2 (1.1)	9.8 (0.9)	9.8 (1.1)
Cadence (step/min)	113.5 (3.7)	112.6 (3.7)	114.2 (2.9)	113.0 (2.5)	108.3 (7.5)	108.8 (8.2)
Velocity (m/s)	1.3 (0.1)	1.2 (0.1)	1.3 (0.1)	1.3 (0.1)	1.2 (0.1)	1.2 (0.1)
Pelvic obliquity (°)	–0.3 (1.8)	–0.8 (2.5)	–1.2 (1.6)	–1.0 (1.7)	–0.8 (2.3)	–0.9 (2.3)
Pelvic tilt (°)	7.3 (2.8)	7.8 (3.7)	7.5 (4.0)	7.3 (3.9)	9.1 (3.1)	8.7 (3.3)
Pelvic rotation (°)	–5.1 (3.9)	–5.0 (2.9)	–4.3 (2.7)	–4.5 (3.9)	–0.5 (5.0)	–4.5 (4.8)
Hip abd/add (°)	–7.1 (1.8)	–7.2 (3.1)	–8.1 (3.0)	–7.6 (1.5)	–7.7 (2.1)	–7.2 (1.9)
Hip flex/ext (°)	–12.2 (5.6)	–10.7 (7.7)	–12.8 (6.7)	–13.1 (6.8)	–11.0 (4.7)	–11.9 (4.5)
Hip intr/extr (°)	0.5 (9.0)	1.8 (10.1)**	–1.4 (9.2)	1.2 (8.7)*	4.6 (10.1)	1.6 (8.4)**
Knee abd/add (°)	9.0 (1.8)	8.6 (1.1)	8.4 (2.7)	8.6 (1.8)	9.2 (2.4)	8.8 (2.1)
Knee flex/ext (°)	10.6 (2.7)	10.8 (3.2)	12.1 (2.4)	10.7 (3.3)	9.2 (3.3)	9.1 (2.9)
Knee intr/extr (°)	4.5 (8.6)	10.9 (6.8)*	15.2 (7.8)	13.2 (8.8)**	9.6 (7.7)	10.8 (6.6)
Ankle dors/plant (°)	4.5 (3.7)	5.6 (3.9)	5.4 (2.5)	4.7 (4.9)	6.3 (3.3)	7.3 (2.9)
Foot progression (°)	–7.3 (2.9)	–6.4 (2.9)	–7.2 (2.9)	–6.5 (3.3)	–8.0 (3.6)	–7.4 (2.9)

Mean angular values (m) for the movement range of the pelvis and the left lower limb with standard deviation (SD), abd/add – adduction/abduction, flex/ext – flexion/extension, intr/extr-internal/external, dors/plant – dorsal/plantar
Statistically significance differences at: * $\alpha = 0.05$, ** $\alpha = 0.01$, *** $\alpha = 0.001$

Table 3. Repeatability two measurements taken in each session (40 cycles) and for only the first measurement in each session (20 cycles)

	Inter-session repeatability (4 × 10 cycles)			Inter-session repeatability (2 × 10 cycles)		
	session I	session II	session III	session I	session II	session III
Stance phase (%)	59.8 (1.4)	59.6 (1.1)	60.2 (0.8)	59.7 (1.5)	59.5 (1.0)	60.2 (0.9)
Swing phase (%)	40.2 (1.4)	40.4 (1.1)	39.8 (0.8)	40.3 (1.5)	40.5 (1.0)	38.8 (0.9)
Double support phase (%)	9.6 (0.8)	9.2 (1.0)	9.8 (1.0)	9.7 (0.7)	9.1 (1.0)	9.8 (0.9)
Cadence (step/min)	113.0 (3.7)	113.6 (2.8)	108.5 (7.8)	113.5 (3.7)	114.2 (2.9)	108.3 (7.5)
Velocity (m/s)	1.3 (0.1)	1.3 (0.1)	1.2 (0.1)*	1.3 (0.1)	1.3 (0.1)	1.2 (0.1)
Pelvic obliquity (°)	–0.5 (2.2)	–1.1 (1.7)	–0.9 (2.3)**	–0.3 (1.8)	–1.2 (1.6)	–0.8 (2.3)**
Pelvic tilt (°)	7.5 (3.2)	7.4 (3.9)	8.9 (3.2)***	7.3 (2.8)	7.5 (4.0)	9.1 (3.1)***
Pelvic rotation (°)	–5.0 (3.4)	-4.4 (3.3)	–4.7 (4.8)	–5.1 (3.9)	–4.3 (2.7)	–5.0 (5.0)
Hip abd/add (°)	–7.2 (2.5)	–7.9 (2.4)	–7.4 (2.0)	–7.1 (1.8)	–8.1 (3.0)	–7.7 (2.1)
Hip flex/ext (°)	–11.5 (6.7)	–13.0 (6.4)	–11.5 (4.6)*	–12.2 (5.6)	–12.8 (6.7)	–11.0 (4.7)
Hip intr/extr (°)	1.1 (9.5)	-0.1 (8.9)	3.1 (9.3)*	0.5 (9.0)	–1.4 (9.2)	4.9 (10.1)***
Knee abd/add (°)	8.8 (1.5)	8.5 (2.2)	9.0 (2.2)	9.0 (1.8)	8.4 (2.7)	9.2 (2.4)
Knee flex/ext (°)	10.7 (3.0)	11.4 (2.9)	9.2 (3.1)***	10.6 (2.7)	12.1 (2.4)	9.2 (3.3)*
Knee intr/extr (°)	12.7 (7.8)	14.2 (8.3)	10.2 (7.1)***	14.5 (8.6)	15.2 (7.8)	9.6 (7.7)***
Ankle dors/plant (°)	5.1 (3.8)	5.0 (3.9)	6.8 (3.1)	4.5 (3.7)	5.4 (2.5)	6.3 (3.3)
Foot progression (°)	–6.9 (2.9)	–6.8 (3.1)	–7.7 (3.2)	–7.3 (2.9)	–7.2 (2.9)	–8.0 (3.6)

Mean angular values for the movement range of the pelvis and the left lower limb with standard deviation (SD), abd/add – adduction/abduction, flex/ext – flexion/extension, intr/extr-internal/external, dors/plant – dorsal/plantar
Statistically significance differences at: * $\alpha = 0.05$, ** $\alpha = 0.01$, *** $\alpha = 0.001$

the results found for gait velocity proved to be not repeatable between sessions, which is in accordance with what was found by Kadaba et al. [11] and Steinwender et al. [9]. It must be emphasized that change in gait velocity can influence changes in kinematic parameters [2, 12–14].

Within session, all kinematic parameters of the pelvis were repeatable in all planes. Between sessions, based on both one (20 cycles) and two measurements (40 cycles), an assessment of pelvic rotation was found to be repeatable. These results are consistent with the research by McGinley at al. [1], who, based on a literature review, noticed that repeatable results occur in the case of pelvic movements in the transverse plane. This has been confirmed by Steinwender et al. [9], who obtained repeatability for this parameter both in a group of healthy children and those with cerebral palsy (CP). Schwartz et al. [2] and Manca et al. [3] also confirmed that pelvic rotation is one of the most repeatable parameters. Researchers explain that pelvic rotation is essentially free of palpation errors and depends primarily on the transverse plane orientation of the line connecting the anterior superior iliac spines (ASIS).

In the case of pelvic movements in the frontal plane, the authors did not observe repeatability between sessions. This may be explained by this parameter's susceptibility to the influence of experimental errors as observed by Schwartz et al. [2] due to the fact that pelvic motion depends primarily on the vertical alignment of the ASIS markers, which requires manual palpation and alignment. However, Manca et al. [3] and McGinley et al. [1] indicated good repeatability for pelvic obliquity. Research by Leardini et al. [15], which examined inter-examiner variability in children, also confirmed that pelvic obliquity is one of the most repeatable parameters.

The authors did not observe repeatable results for pelvic movements in the sagittal plane between sessions either on the basis of one or two measurements. This is consistent with McGinley et al. [1], who, based on a literature review, stated that pelvic tilt showed lower reliability than other pelvic angles. Likewise, Schwartz et al. [2] and Manca et al. [3] noticed a low repeatability of pelvic movements in this plane when examining healthy adults. Similar outcomes, this time when examining healthy children and those with CP, were obtained by Steinwender et al. [9]. Researchers observed high variability in the pelvic tilt measurements of both groups; however, repeatability for this parameter proved to be better in the group of children with CP when compared to the group of healthy children. In contrast, Assi et al. [7] observed in children a certain amount of uncertainty when assessing pelvic tilt. According to Schwartz et al. [2], pelvic tilt is the most likely among all kinematic parameters of the pelvis to be influenced by experimental errors, due the need for palpation of the third marker on the sacrum.

Within one session, hip joint movements in the frontal and sagittal planes were repeatable, but no repeatability was observed for hip joint rotation. Between sessions, measurements in the sagittal plane were repeatable both in the case of one or two measurements. These results are compatible with Manca et al. [3] and in the literature review provided by McGinley et. al. [1]. Schwartz et al. [2] also observed that adduction/abduction of the hip joint was overall the most reliable of the hip angles. Closer inspection, however, proved this parameter to be also susceptible to errors deriving from its methodology. Despite this, the repeatability for his parameter is high not only for adults, but also for children [2]. This was confirmed by Steinwender et al. [9], who obtained good repeatability for hip joint adduction/abduction both in healthy children and in children with CP.

In the present study, hip joint flexion/extension after one measurement (20 cycles), was found not to be repeatable between sessions, which is in contrast to the results obtained after taking two measurements within a session (40 cycles). It is believed this discrepancy may result from the number of data subjected to statistical analysis. In practice, such an examination can be conducted only once a visit, and in this study, the examination did not provide repeatable measurements for flexion/extension of hip joint. However, the literature review conducted by McGinley et al. [1] indicated that hip joint movements in the sagittal plane are repeatable. The results obtained by the authors are close to those found by Schwartz et al. [2]. This group of researchers noticed that this parameter was not as repeatable as the adduction/abduction of hip joint, but more repeatable than hip joint rotation.

In hip joint rotation, the authors did not notice repeatability either within session or between sessions. This is consistent with the results of research by Schwartz et al. [2], Manca et al. [3], Gorton et al. [6], Assi et al. [7], Steinwender et al. [9] and Kadaba et al. [11] regardless of whether the study was conducted on children or adults, healthy subjects or those with various medical conditions. All researchers agree that hip joint rotation is characterized by the greatest amount of variability. Depending on the applied procedure, experimental errors can stem from a number of causes. Assi et al. [7] explain that the lack of repeatability is caused by the inappropriate placement of markers on the thigh. On the other hand, Schwartz et al. [2] suggest that great deal of variability in hip joint rotation can be attributed to knee alignment sources, such as knee joint rotation.

Within session, adduction/abduction and flexion/extension of the knee joint within session were found to be repeatable, while knee joint rotation was not repeatable. Between sessions, repeatable results were obtained for knee joint movements in the frontal plane. In this case, the results presented by some researchers were not congruent. According to McGinley et al. [1], some authors emphasized good repeatability for knee adduction/abduction. Schwartz et al. [2] obtained different results, and noticed the significant influence of experimental errors on this parameter. In addition, Steinwender et al. [9], while examining repeatability in children, observed that adduction/abduction of the knee joint was not repeatable. According to these authors, these discrepancies can be caused by variability in the particular stages of the gait cycle and correspond to the knee joint flexion/extension parameter, which signifies that knee joint movements have a bigger range in the frontal plane when the joint is in flexion.

Knee joint flexion/extension movements between sessions were not repeatable. Schwartz et al. [2] also confirmed the significant influence of errors in knee flexion/extension. Additionally, when trying to determine inter-trial errors, they observed significant variability of this parameter in the gait pattern, which, as researchers see it, detracts from the reliability of this data. In contrast, McGinley et al. [1] noticed that different researchers obtain good repeatability for this parameter both in adults and children.

For knee joint rotation, similarly to hip joint rotation, no repeatable results were obtained between sessions, which is consistent with the results achieved by other researchers. Benoit et al. [16] and Lafortune et al. [17] indicate that the range of motion and direction of knee rotation are highly variable. This causes difficulty in interpreting data. Manca et al. [3] suggest that the high variability of knee joint rotation might be due to the positioning of epicondyle and malleoli markers, which are the basis for relevant anatomical frame orientations in that plane. According to Leardini et al. [15], the knee joint is among the group of joints where skin movement is the most intensive. Therefore, variability may result from artifacts that occur when following the movement of the markers on the skin.

For foot progression, repeatable results were obtained both within session and between sessions. In contrast, Schwartz et al. [2], Steinwender et al. [9], and Kadaba et al. [11] observed low repeatability of this parameter. Schwartz et al. [2] considered the results worrying, as foot progression is crucial in the planning of tibial derotational osteotomy. According to researchers, the errors in this parameter derive from the placement and alignment of foot markers. This assumption was confirmed by post-hoc examination, which showed discrepancies in an assessment of the proper placement of markers. Therefore, it can be assumed that the researcher taking measurements in this study used a sound method when assessing the proper placement of markers on the foot.

Within one session and between sessions, dorsal/plantar flexion of foot was found to be repeatable. Similar results in adults were obtained by Schwartz et al. [2], Manca et al. [3] and Kadaba et al. [11]. Also, Gorton et al. [6] and Steinwender et al. [9] observed good repeatability of this parameter in children. The results of other researchers included in the review by McGinely et al. [1] confirm that this parameter is characterized by low variability.

The reason for such discrepancies in the results by various researchers may be attributed to many causes. First of all, intra-examiner repeatability was analysed in this research; other researchers also concentrated on the inter-examiner. Schwartz et al. [2] also examined the ratio of inter-trial/inter-examiner variability, trying to assess the influence of experimental errors on measurement reliability. Among other reasons for the discrepancies, one may come from the application of different procedures and research models. Schwartz et al. [2] indicated that the application of the biomechanical model, which has a hierarchical structure, can generate experimental errors from proximal to distal distances. This signifies that the recorded experimental errors in hip, knee and ankle joints might have been caused by errors that occurred within the pelvic angles. Moreover, hip-knee errors might be connected with the location of the hip and knee joint centres. Discrepancies in the results may also arise from: sample size, methods of statistical analysis and the timeframe of marker placement and their alignment. In addition, according to Gorton at al. [6] and Chambers and Goode [18], the accuracy of measurement systems used, if not properly configured and calibrated, can influence the variability of results to a small extent. Finally, variability may be influenced by other, unidentified factors.

The values presented in this paper are valid only for the laboratory-setting that was studied herein. One should be very careful about transpositioning these results against the reliability of gait assessments conducted in other centres. On the other hand, they can serve as a point of reference and a comparison with the data collected from other laboratories. Hence the reason why it is necessary to assess the repeatability of measurements within each laboratory in accordance with its adopted methodology as well as over different points in time. The assessment of the repeatability and reliability of measurements taken in different gait analysis laboratories requires standardized research procedures pertaining to the applied procedure, the way data is collected (e.g. sample size, the size of the study group, the number of trials registered for each subject) and statistical analysis methods.

Some limitations of this study stem from the fact that the sessions were conducted on healthy subjects. For this reason, any conclusions drawn here cannot be generalized and applied to individuals with gait abnormalities. Gorton et al. [6] suggested that gait abnormalities may pose a greater challenge when it comes to marker placement, and therefore lead to a greater variability of measurements especially when conducted by different examiners. There is still no applicable coefficient that would allow one to determine the source of errors (whether internal or external) that disturb the repeatability of results. Moreover, this study concentrated on adult subjects, so there is a need to determine the repeatability of measurements for children.

The results presented herein are yet another element in the discussion about the repeatability and reliability of gait analysis. It is believed that such research is indispensable as to understand and analyse the sources of errors for objective gait analysis and to determine the quality and reliability of measurements. It is also the first step towards increasing reliability and allowing researchers to draw appropriate conclusions in order to make good diagnostic and therapeutic decisions, and to meet the demands that EBM places on scientists as well as medical practitioners.

Conclusions

1. The temporal and spatial parameters of gait are highly repeatable.
2. Conducting gait analysis by only one researcher does not guarantee obtaining repeatable results for all kinematic parameters, either within one session or between sessions, which requires caution in interpreting results.
3. Hip and knee joint rotation were the parameters that provided the most difficulty in obtaining repeatable results. For this reason, diagnostic and therapeutic decisions based on such data require the utmost thoughtfulness.
4. There is a need to determine the influence of other sources of error on the repeatability of results in gait analysis, e.g. the size of the study group, the number of trials conducted for each subject or the timeframe and alignment of marker placement.
5. It is necessary to conduct research on the measurement repeatability in each laboratory.
6. A comparison of repeatability between laboratories requires standardising data collecting and analysis procedures.

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