Flexible software for the elimination of the markers used in the analysis of human posture through kinect®sensor

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Abstract

From a cibernetic approach, the body system can be defined like a net of structural and functional related subsystems with motor equifinality inside the concept of balance, energetic economy and comfort: therefore the ideal posture is the one that allows the maximum effectiveness of motor gesture, in absence of pain with the maximum energetic economy. The present study research is based on the necessity to individuate a real objective evaluation system of the postural parameters, inexpensive and of simple use compared to the evaluation instruments in use already scientifically validated. The instrument used in this study is the Microsoft Kinect®, gaming platform combined with the Xbox console. Created by Microsoft in the field of play, the Microsoft Kinect® for years has entertained millions of consumers through the Motion Capture System, the recording of movement through cameras and instant or deferred replay. The primary aim of this randomized controlled single-blind research is the demonstration that, despite being commonly defined objective the evaluation systems that utilize markers, is essential to look for an alternative evaluation method to minimize the systematic human error.

The results demonstrate the real validity of Kinect®, and have verified the reliability of the data obtained from the assessment, showing the scientific reliability of this innovative objective evaluation method in rehabilitation-clinical field.

Key words: postawy, oceny stanu pacjenta, Kinect®sensor (posture, patient assessment,

Kinect®sensor

Introduction

From a cibernetic approach, the body system can be defined like a net of structural and functional related subsystems with motor equifinality inside the concept of balance, energetic economy and comfort: therefore the ideal posture is the one that allows the maximum effectiveness of motor gesture, in absence of pain with the maximum energetic economy.

The present study research is based on the necessity to individuate a real objective evaluation system of the postural parameters, inexpensive and of simple use compared to the evaluation instruments in use already scientifically validated.

It will first be discussed and focuses the study on the ability of an evaluation system to be objective.

The primary aim of this randomized controlled single-blind research is the demonstration that, despite being commonly defined objective the evaluation systems that utilize markers, is essential to look for an alternative evaluation method to minimize the systematic human error.

The instrument used in this study is the Microsoft Kinect®, gaming platform combined with the Xbox console. Created by Microsoft in the field of play, the Microsoft Kinect® for years has entertained millions of consumers through the Motion Capture System, the recording of movement through cameras and instant or deferred replay.

The Kinect® is an RGB camera, equipped with an infrared system, capable of capturing frames in 3D.

The software allows the simultaneous recognition within the scene of a maximum of 6 users, for two of which it is possible the extraction of 20 landmarks via skeleton capability.

This functionality allows, through sensor detection, the assumption of a specific static posture for few seconds of the user, the extrapolation of the scheme of the user's skeleton and the identification of 20 principal landmarks.

The SDK (Software Development Kit) for Windows platform includes the drivers that give the possibility to develop C++, C# and Visual Basic application using the following information that directly originate from the device sensors:

- Raw Sensors Streams: access to the low level streams of the sensor of deepness, the RGB camera and microphones;
- Skeletal tracking: access to the functionality that allows to realize the image of the principal parts of the skeleton of one or two users framed by the device;
- Advanced Audio Features: audio processing. Numerous noise-canceling functions are included like identification of the sound source, and integration with the API of Microsoft Windows Speech Recognition.

The Kinect®, may have the potential to be used as a tool to measure the temporal aspects of spatiotemporal gait, but standardized methods should be established, and future tests with both healthy and clinical participants are needed in order to integrate the Kinect®, as a tool of analysis of the clinical path. [1]

This widely available, low cost and portable system able to provide physicians with significant benefits for the measurement of certain spatio-temporal gait parameters. However, caution must be taken when choosing the outcome variables such as some commonly reported variables cannot be measured precisely. [2]

Currently you cannot make a universal clinical utility generalization of CAGS in orthopedics. However, there is no evidence to support using the WBB and Xbox Kinect®, as a means to obtain reliable and valid measures COP. The Wii Fit game can specifically provide reliable and valid measures for predicting the risk of falling. [3]

In this research study, we wanted to improve the ability to assess static posture Kinect®, through the creation of a software (Sa.B.B. -Safe Bead Balance-).

We compared the data obtained with the data of a modern assessment system and scientifically validated, with the aim to show that this device could be trusted, cheaper and easier to use.

The study group was analyzed with the Global Opto-electronic Approach for Locomotion and Spine (G.O.A.L.S), a scientifically validated system [4,5,6] in this way we are able to analyze the differences between the method of choice and to understand the objectives and the ability to future use of this technology in the field of research.

For the study group has been created a special software adapted to this research study, the Sa.B.B. software (Safe Bead Balance), used to verify the theoretical foundations of potential Kinect® in clinical practice.

Materials and Methods

This experimental study and the research protocol is compatible with the Declaration of Helsinki. and all subjects involved in the study have been informed about the procedure and the aim of the research and signed the informed consent.

This study was conducted at the University Centre of Physical and Rehabilitation Medicine, „Gabriele D'Annunzio" University in Chieti.

The aim of identifying comparable objective postural evaluation data using two evaluation systems compared to the evaluation of the operator:

- Global Opto-electronic Approach for Locomotion and Spine (G.O.A.L.S)
- Postural evaluation system by Sa.B.B. software

In this study research were included 50 healthy subjects of both sexes, aged between 7 and 65 years old.

It was not performed any kind of treatment but only a non invasively postural evaluation.

Inclusion criteria for the entire sample studied were:

- Healthy subjects, without any form of muskulo-skeletal pathology

Exclusion criteria for the entire sample studied were:

Presence of any type of muskulo-skeletal pathology

- Subject under 1 meter of height

All subjects were evaluated by the clinician and subsequently by the systems chosen for the study research.

The Global Opto-electronic Approach for Locomotion and Spine (G.O.A.L.S) requires to evaluate the subject undressed for the application of the markers.

The markers placed during the evaluation are 27:

- 13 small, for the acquisition of:
- C7-S3 SPINE
- PSIS (Posterior Superior Iliac Spine)
- 14 large, for the acquisition of
- facial landmark (cheekbones and chin)
- acromial landmark
- clavicular landmark
- sternal landmark
- ASIS (Anterior Superior Iliac Spine)
- popliteal landmark
- calcaneal landmark

Once the application of the markers, the evaluative process has continued with the subject's static acquisition.

The Global Opto-electronic Approach for Locomotion and Spine (G.O.A.L.S) evaluation required 30 minutes.

Finally, the acquisition with the Microsoft Kinect®, has been carried out.

Each examination with the Kinect®, has required a total of about 3 minutes, without the necessity to undress the subject.

Global Opto-electronic Approach for Locomotion and Spine (G.O.A.L.S)

This evaluation system is able to carry out biometric measurements and real-time 3D-reconstruction of the spine, allowing a precise evaluation with objective data, screening and/or individuate numerous painful areas.

The application of markers or the selection using the software of the points to analyze are required for the analysis.

The system creates instantly the map of the whole body, with the 3D-reconstruction of the skeletal structure and of the spine.

The software found on a mathematic model based on the single clinical case elaboration and not on statistical analysis.

The software create 30 photograms per second, each analysis has the duration of 2 seconds.

The biometric measurements are filled with other data like the calculation of specific angles, like the surface calculation, Cobb angles etc.

The subject is analyzed in the various spatial planes: frontal (anterior and posterior), sagittal (right and left lateral) and transverse (from above). (fig,1)

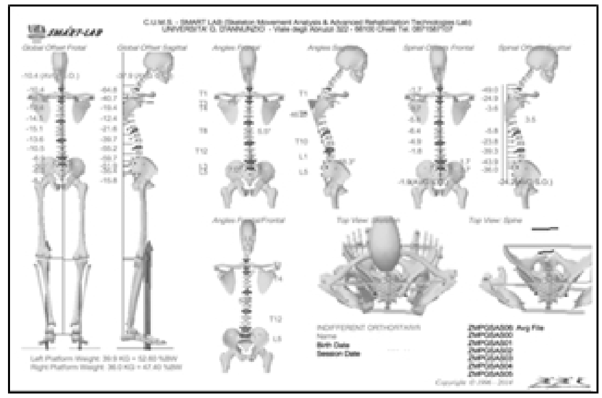

Figure 1 Final report of Global Opto-electronic Approach for Locomotion and Spine (G.O.A.L.S)

The data are acquired in standing position, while the subject watches a point of reference in front of him.(fig 2)

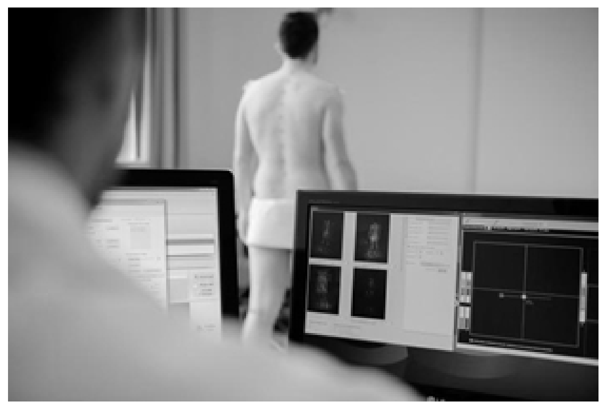

Figure 2 Acquisition of data with Global Opto-electronic Approach for Locomotion and Spine (G.O.A.L.S)

The exam is realized through the following parameters:

Structural symmetry

Zygomatic symmetry

Shoulder symmetry

The shoulder symmetry is calculated like the inclination expressed in angles of the line passing through markers positioned by the operator on the right and left acromion compared with the horizontal plane.

This indicator quantifies structural misalignment of the dorso-lumbar spine.

Pelvic symmetry:

The pelvic symmetry is calculated like the inclination expressed in angles of the line passing through markers positioned by the operator on the right and left antero-superior iliac spine compared with the horizontal plane.

This indicator quantifies structural misalignment of the pelvic girdle and needs to be compared with the indicator of right and left pelvic nutation calculated on sagittal plane.

Scapular symmetry:

The scapular symmetry is calculated like the inclination expressed in angles of the line passing through markers positioned by the operator on the right and left inferior apix of the scapula compared with the horizontal plane.

This indicator quantifies paramorphisms of the trunk.

PSIS simmetry:

The PSIS symmetry is calculated like the inclination expressed in angles of the line passing through markers positioned by the operator on the right and left posterior superior iliac spine compared with the horizontal plane.

This indicator quantifies misalignment of the pelvis.

Cervical arrow:

The cervical arrow is calculated like the distance, expressed in millimeters, of the apex of the cervical concavity from the posterior line (absolute vertical passing through the tangent to the aftermost point of the subject). This value is used to evaluate a reduction or increase of the cervical lordosis.

Dorsal arrow:

The dorsal arrow is calculated like the distance, expressed in millimeters, of the apex of the cervical convessity from the posterior line (absolute vertical passing through the tangent to the aftermost point of the subject). This value is used to evaluate a reduction or increase of the dorsal kyphosis.

Lumbar arrow:

The lumbar arrow is calculated like the distance, expressed in millimeters, of the apex of the lumbar concavity from the posterior line (absolute vertical passing through the tangent to the aftermost point of the subject). This value is used to evaluate a reduction or increase of the lumbar lordosis.

Condylar arrow:

The condylar arrow is calculated like the distance, expressed in millimeters, of the apex of the condylar concavity from the posterior line (absolute vertical passing through the tangent to the aftermost point of the subject). This value is used to evaluate alteration of the lower limb (flexum or recurvatum of the knee).

Malleolar arrow:

The malleolar arrow is calculated like the distance, expressed in millimeters, of the apex of the malleolar concavity from the posterior line (absolute vertical passing through the tangent to the aftermost point of the subject). This value is used to evaluate alteration of the lower limb (flexum or extension of the ankle).

Postural Evaluation by Sa.B.B. Software

The system selected for study is the Microsoft Kinect®, toolkit. It allows an evaluation method without the utilization of markers and direct interaction of the operator. The use of Kinect®, is related in this study to a dedicated software (fig 3).

Figure 3 Sa.B.B. Software Microsoft Kinect®,

This software is able to reconstruct a 3D-avatar called Skeletal View, composed by 20 anatomical landmarks.

The software works at 30 frames per second frequency and each single analysis have the duration of 5 seconds, with an average capture of 150 frames.

The obtained avatar is formed by two projections, frontal and sagittal, that contain useful postural parameters.

Frontal projection:

Height of the subject and length of the limbs:

The height of the subject and the length of the limbs are recorded to highlight real or spinal dysmorphism related asymmetries.

Distance:

Distances are captured from the most important anatomical landmarks: acromion landmark, ASIS landmark, patellar and malleolar landmarks. This data highlight rotations of humeral-scapular girdle, pelvic girdle or tibial anteposition.(fig 4)

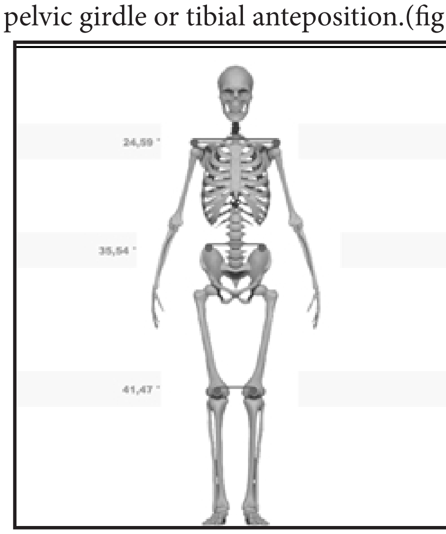

Figure 4 Distance and anatomical landmarks

Horizontal angles:
The horizontal angles are elaborated through a straight line along three main axes: acromial line, ASIS line and patellar line. Inclinations that differ from 0 degrees allows to reveal asymmetry on frontal plane of humeral-scapular girdle and of pelvic girdle.(fig 6)

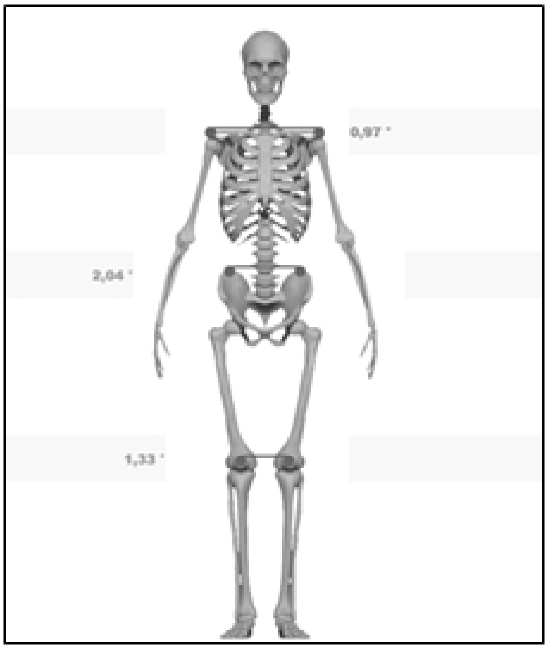

Figure 6 Horizontal angles

Vertical angles:
The vertical angles are elaborated through a straight line passing along the central point of the avatar, inclinations that differ from 0 degrees allows to reveal inclination of the head, of the cervical spine, asymmetry on frontal plane of C7-L1 and L1-S1 column tract. These information are useful to highlight possible dismorphisms of the spine on frontal plane, like scoliosis.(fig 7)

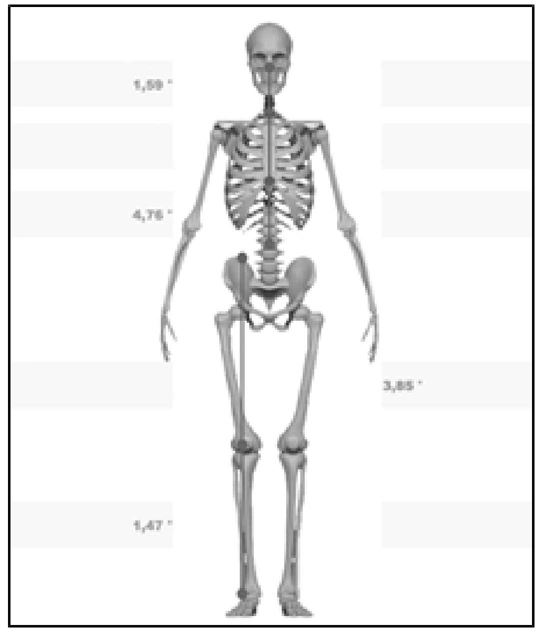

Figure 7 Vertical angles:

Sagittal projection

Vertical angles:
With the same elaboration explained for the horizontal projection, the software permit to individuate inclinations on sagittal plane, important data to observe anteposition of the head and the spinal curves on the sagittal plane.(fig 8)

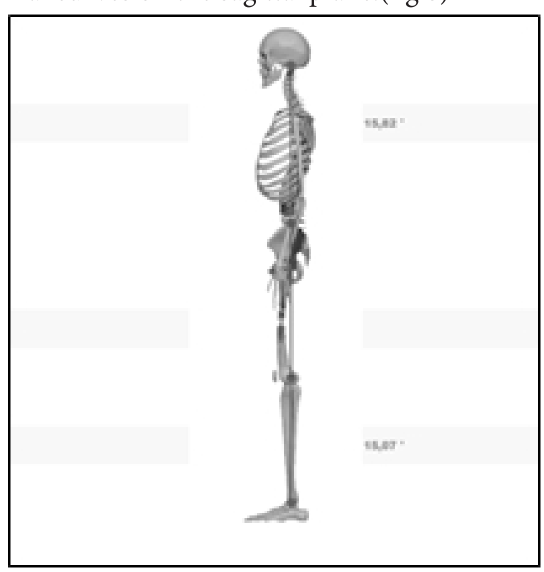

Figure 8 Sagittal projection and vertical angles

Results
The data resulting from the two evaluation systems have different measurement scales, being different the two software with which the measurements were made, but they are of easy comparison. Sensitive data that were specifically analyzed are:

- Bisacromial line,
- Patellar line
- Bisiliac line, Ideal line between right and left
- ASIS (Anterior Superior Iliac Spine)

These data were chosen also because this subsystems are the most representative on frontal plane of the posture [14,15,16]. The rotula position is a direct consequence of the attitude ankle foot subsystem; it has been taken into account the patellar line and not the malleolar line both because this area was easier to markerize and so analyze with the G.O.A.L.S. System in comparison with the bi-malleolar line.

In order to compare the two valuation methods and highlight the significance of the results, the data taken into consideration was the cranial position of right side body of landmarks identified.

Collected data have been processed and analyzed with the Paired Simple T-Test through statistical software NCSS and in order to show whether the two methods showed the same postural parameters, it is considered the data that confirmed the two hypotheses (cranial position not cranial position in right side of the body).

The analysis of data show not significant statistical difference, so the results obtained with the two evaluation methods can be overlapped.

This statistical analysis showed a low statistical significance of differences in postural assessment data obtained from the assessment through G.O.A.L.S. evaluation, software Sa.B.B. and subjective evaluation of the operator : in particular regarding the patellar line and bisacromial line.(fig 9,10)

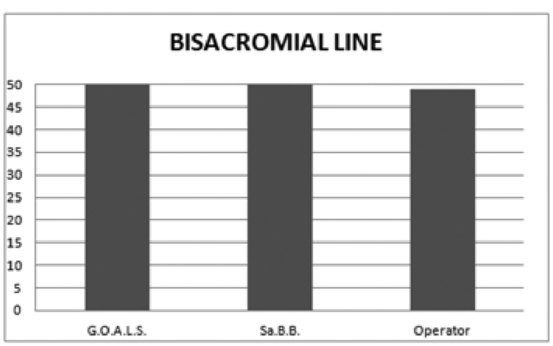

Figure 9 Bisacromial line differences in postural assessment data obtained from the assessment through G.O.A.L.S. evaluation, software Sa.B.B. and subjective evaluation of the operator

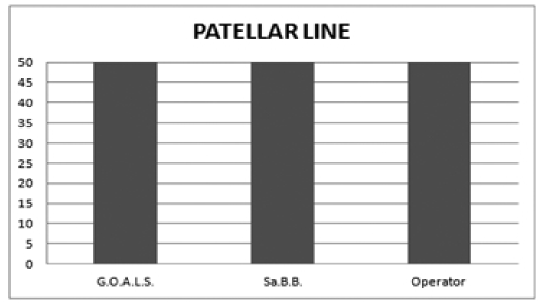

Figure 10 Bisacromial line differences in postural assessment data obtained from the assessment through G.O.A.L.S. evaluation, software Sa.B.B. and subjective evaluation of the operator

As regards the evaluation of the iliac line, the comparison between the methods showed a statistically significant difference in postural data obtained from the system SaB.B. compared to that obtained from the G.O.A.L.S. Assessment, which has been confirmed by the assessment performed by the operator.(fig 11)

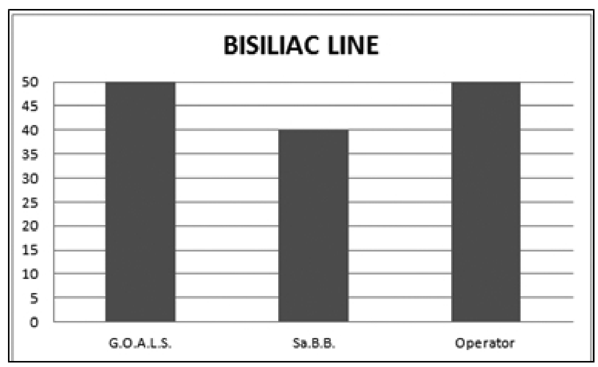

Figure 11 Bisiliac line differences in postural assessment data obtained from the assessment through G.O.A.L.S. evaluation, software Sa.B.B. and subjective evaluation of the operator

Discussion and conclusion

The analyzed instrument in this study was the Sa.B.B. Software, compared with G.O.A.L.S. system, scientifically validated and clinician evaluation, that is subjective and liable to human error.

The Microsoft Kinect®, also known as the Xbox Kinect®, includes new and potentially much improved depth and image sensors that can increase the accuracy for evaluating postural control and balance.[7]

Many studies suggest that the Kinect®, technology, can effectively evaluate the kinematic strategies of postural control. Given the potential benefits which could then become a useful tool for evaluating postural control in the clinical setting. [8] In this paper, we present a software for the evaluation of human posture without markers used in the analysis.

This software is based primarily on sequences of images captured by a camera and image processing tools through artificial vision.

Unlike the optoelectronic systems, which record only the coordinates of the markers, a video-based system provides more visual information and flexibility which may be exploited in different applications. [9,10]

The automatic detection used by the Kinect reduces the execution time of evaluation, thus results in the analysis of human posture carried out in only five seconds.

The purpose of this study was to evaluate the validity and reliability of the kinematic data recorded using a software without the use of analysis of markers , the Kinect in the static postural evaluation, comparing the results with the subjective evaluation of the operator and the objective evaluation of a sophisticated three-dimensional postural evaluation system (G.O.A.L.S.).

The Kinect®, is equipped with the basic functions of motion capture and with some minor adjustments will be an acceptable tool for measuring an instantaneous capture of a temporal frame, but this instrument needs more sensitivity and implementation before it can be utilized for clinical use, for this motivation a sophisticated software and hardware is necessary to improve the Kinect® . In this research study, we created and developed a new software for improving the capability and the precision of the Kinect® in the static postural evaluation, the Sa.B.B software.

The assessment methodology has allowed us:

- to assess the subjects in just 5 seconds without the use of any marker of bony prominences
- without the need to strip the patient
- with an average of scientifically valid scanned images.

The aim of this study is to assess the validity software Sa.B.B. trough Kinect® sensor, using it to evaluate the postural parameters. The results indicated various levels of accuracy for different parameters.

The results suggest that the software Sa.B.B. using the Kinect® sensor has had a good precision.

The average value of the space-time parameters derived from the sensor Kinect®, and the motion monitoring system, as well as the average of the images acquired as the static phase, oscillations as dynamic phase, showed no major differences between the two devices taken into consideration and with the evaluation of the operator.

In literature, since the accuracy of the Kinect®, sensor varies with the location and the direction [11], so the timing error of an event such as the assessment may be influenced by the participant position relative to the sensor.

One possible explanation is that the Kinect® sensor had error lower closest to the sensor for measuring objects [11], the Kinect® is designed for the videogame interaction using body movements on a static grounding surface; the movement condition may interfere with the identification of the subject position.

Another possible variation could be the distance between the participants and the Kinect®, sensor that must be constant from the participants [12]. This parameter has been constant in the assessments of the subjects analyzed.

In a research study, the sensors based on the knee and hip joint angles Kinect®, measured during a evaluation seem to follow the trend of the joint angles based on motion tracking system; however, there were no significant systematic errors in magnitude.

In other studies, other details are similar to the results of Pfister et al. [13] where the knee bending angle has reached an unrealistic negative value, indicating the hyperextension of the knee (also observed in Pfister et al.).

The angle of hip joint derived from the sensor had a smaller error when compared with the angle knee. Underrated hip flexion and hip extension overestimated likely occurred because the knee joint to the sensor base was set back from the reference.

The hip angle variance derived from the sensor was smaller than the one derived from the motion tracking system.

Further analysis indicates that this was because the Kinect®, sensor did not detect inter-participant variability of the anterior-posterior tilt pelvis.

According to the ISB Recommendation [14], the pelvic tilt is related to the relative position between cephalo-caudal ASISs and mid PSISs.

Because of the morphological differences in the pelvis of the participants, the pelvic tilt angles may differ resulting observed variability inter-participant of the hip joint angle.

In our study, the value of angle of pelvis inclination was evaluated in all participants using the Sa.B.B System and the G.O.A.L.S.

With the pelvic coordinate system based on software Sa.B.B. created in this study, the position of the pelvic tilt was not stackable to the results obtained with G.O.A.L.S. system of evaluation of posture and with the operator evaluation.

Therefore, the underestimation of the pelvic tilt variability with the use of Kinect could have caused a low angle hip variability and thus the difference in the results between the S.A.B.B. system and the other two methods of evaluation.

Moreover, the shortenings, the hypertone and the functional restrictions of this structures can be given by reological deficits of a aponeurotic--muscular interconnection or by asymmetric responses; therefore the less active or passive tension, or the joint or tissue dysfunctions can influence, through the specific tissutal and neurological interconnection on the whole body system because all the anatomical regions can be considered mechanical and neurological connected [16].

Conclusions

In summary, to the define the concept of posture in the neuroscience field, it's possible to define "posture like expression of the morpho-sensory--motor interconnection of the evolutive identity" in which the specific neuro anatomical concept about the 3 embryological layers with the metha physical concept is relativized [17].

Basing on these concepts, so on the idea that the body system is a whole but is divided also in other subsystems that can influence the body system itself and that posture is a dynamic and three-dimensional concept, it can be stated that while the G.O.A.L.S. analyze the single components and symmetry of the pelvic girdle, the Sa.B.B. is a global one. It because the Sa.B.B. system is able to analyze the three-dimensional movement of pelvic girdle creating so a morphological evaluation of this segment that is expression of the function and movement and not only a sort of "static picture" of it and so represent a more significant and global data about this analysis.

There were some limitations of this validation study that must be addressed.

The participants were a paralleled even healthy young adults.

Since a difference greater joint angle of 5° is considered a clinically significant difference [18], the study results suggest that the angles of the patellar lines, bis-acromial and joint measured directly with the Kinect®, sensor can be used for the analysis of the clinical posture.

The analysis of posture should be based on a relative comparison between healthy and pathological groups, it would be important to know if the sensor can differentiate the pathological gait parameters, and that should be further addressed in future studies.

In order to minimize the missing common centers, in this sensor study was placed in front of the participants during the static evaluation [19].

The results of Pfister et al. [13] has shown that when the Kinect®, sensor is placed in a 45° angle to the sagittal plane.

In summary, the precision with the sensor to detect postural parameters differed between the various postural parameters of the position of the subject.

For hip joints, the sensor able to follow the trend of common trajectories, but with the substantial error magnitudes.

Unlike the other two techniques, evaluating only the two points position between cephalo-caudal ASISs and mid PSISs, the Sab.b. software,trough Kinect®, sensor, allows a three-dimensional reconstruction of the pelvis, thus being able to truly assess the sacrum-iliac-ischium- pubic complex.

The Sa.B.B. software is valid and reliable for the postural evaluation.

The acquisition speed makes it practical and efficient, while the total absence of markers makes it actually error-free by the operator, making the system free of subjectivity.

This study is the first step towards a world of new technological capabilities in diagnostic and rehabilitation.

Conflict of interest

All authors declare that there is no personal interest properties, financial, professional or other of any nature or kind in any product, service or company that could be interpreted as influencing the position presented in this manuscript

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