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Methods of Measurement and evaluation of postural stability using a transportable system

Master thesis

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MASTER'S THESIS ASSIGNMENT

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II. MASTER'S THESIS DETAILS

Master's thesis title in English:

Methods of measurement and evaluation of postural stability using a transportable system

Master's thesis title in Czech:

Metody měření a vyhodnocování záznamů posturální stability pomocí přenosného systému

Guidelines:

Design methods for measurement and evaluation body postural stability of paratroopers, guards, infantry and special foreign units members of Czech army using a pair of Nintendo Wii Fit Balance Boards and Microsoft Kinect camera systems. Focus on the methods for measurement of the center of pressure under the feet (COP) and anatomical points of the body (spine and pelvis) during quiet upright stance in order to determine the health status of the musculoskeletal system and its changes with the respect to different military professions. Using the Microsoft Kinect camera system application, suggest methods of posture measurement in depth maps. Test the proposed methods on at least 30 subjects and statistically evaluate difference between posture in military professions. Evaluate the applicatibility of the methods in clinical practice.

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III. ASSIGNMENT RECEIPT

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7/5/19

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I hereby declare that I have completed this thesis having the topic **Methods of Measurement and evaluation of postural stability using a transportable system** independently and I have included a full list of used references.

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With sincere regards,
Poonam Suthar P.

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Chapter 1 Introduction

Physical fitness is the master key to live the healthy life in revolutionary world and the fast-growing era, today where technologies are raising rapidly and making interaction with our daily routines encourage the healthy life agenda's, one of the main aspect in the human body which makes human body align is our posture and that's why to maintain good posture is very crucial. According to the study related to "why good posture matters" from health Harvard education site its worth to pay attention that good posture is important to balance by standing up straight you centre weight over the feet which also helps body to maintain correct form during exercising and working on the balance will strengthen the abilities[1].

The transportable system described during this study permits to measure spine parameters (mutual position of individual vertebrae), mutual position of the pelvis and chest within the lateral plane, centre of pressure (COP) underneath each feet and centre of gravity (COG). It uses reflective markers also as green markers to mark designated anatomical points that are captured by Microsoft Kinect 2 situated behind the subject and Microsoft Kinect situated to the subject's side. COP and COG are determined using 2 Nintendo Wii Balance Board, stabilometric platforms which are placed next to each other, which is low cost compare to other optical movement capture systems like Optitrack, vicon which is too expensive and needed wide area to evaluate the test such as postural stability it also need more number of cameras and software to evaluate the data, the system which combined in this study required less space lesser tools and less funds.

1.1 Overview of Posture

Posture the approach you hold your body once you are sitting or standing is that the foundation for each movement your body makes and may confirm however well your body adapts to the stresses on these stresses are often things like carrying weight or sitting in an ungainly position. And also the massive one we all experience all day on a daily basis If posture is not optimum the muscles have to work tougher to stay body upright and balance some muscles can become tight and inflexible. Others are inhibited over time these dysfunctional variations impair the body's ability to handle the forces on that. Poor posture inflicts further wear and tear on the joints and ligaments will increase the chance of accidents and makes some organs like lungs

less economical. Researchers have joined poor posture to scoliosis tension headaches and back pain. Though it is not the exclusive reason behind any of them posture can even influence your spirit and also the sensitivity to pain. Thus there square measure loads of reasons to aim for good posture. However it's obtaining tougher these days. Sitting in uncomfortable position for a too much time can encourage poor posture and so can using computers or mobile devices that encourage you to seem downward. Several studies counsel that on the average posture is obtaining worse. Thus what will smart posture appear as if after we cross-check the spine from the front or the back? All thirty three vertebrae ought to seem stacked during a straight line from the side. The spine should have 3 curves one at neck one at shoulders and one at the small of your back. we weren't born with this s formed spine babies spines simply have one curve sort of a C the opposite curves typically develop by twelve to eighteen months as the muscles strengthen these curves facilitate us keep upright and absorb some of the stress from activities like walking and jumping. If aligned properly after we are standing up and should be able to draw a straight line from some extent simply in front of the shoulders to behind the hip the front of knee to a few inches in front of the ankle joint[2].

The definition of the posture is alignment of body elements in an exceedingly relationship to one another at any given movement Posture involves advanced interactions between bones, joints, tissues, skeletal muscles and also the system, each central and peripheral. The quality of those interactions is combined once one considers the close to microscopic sort of human balance, control and movement in regard to gravity. Moreover, with the passage of your time, every organism undergoes modification ensuing from small trauma, frank injuries and also the effects of wellness on the neuromusculoskeletal system that end in the common and distinctive variations of aging posture[3]. Poor Postural stability has been known as a risk issue for lower extremity system injury. The additional weight of Armour carried by troopers can alters static Postural stability and should incline troopers to lower extremity system injuries. However, static Postural stability tasks poorly replicate the dynamic military setting, which places extended stress on the Postural stability system throughout plan of action coaching and combat[4].

Postural stability measures used to assess post injury and post-surgical musculoskeletal somatosensation have gained support from the sports medicine community, and also the effects of prophylactic articulation ankle bracing, foot orthotics, balance coaching, and skill coaching on Postural stability management and athletic performance have all been investigated. However despite the recent advances in postural stability mensuration and also the accrued

relevance of analysis findings to clinical follow, three key issues remain: nomenclature, criterion standards, and technology[5]. Maintaining Postural stability equilibrium needs the central system to method and integrate centripetal information from the modality, visual, and proprioception sensory systems into the choice and execution of acceptable and coordinated contractor responses throughout the joints of the lower extremities, although there are 3 sensory modalities accessible (somatosensory, visual, and vestibular), analysis has known the sensory organs (mechanoreceptors) set in ligaments, joint capsules, and musculotendinous tissues as important sensory sources underneath traditional conditions[6][7]. The choice and potency of contractor corrective responses rely on a balance of strength, flexibility, and muscular endurance throughout the joints of the lower extremities. Each sensory and motor processes are reported to be non-contiguous or altered following orthopaedic injury to the articulation ankle and knee joints. it's in such cases that Postural stability testing is commonly utilized in clinical and analysis settings[8]

The importance of good posture is as much as important as good sleep and eat good so the Different posture of standing are shown below

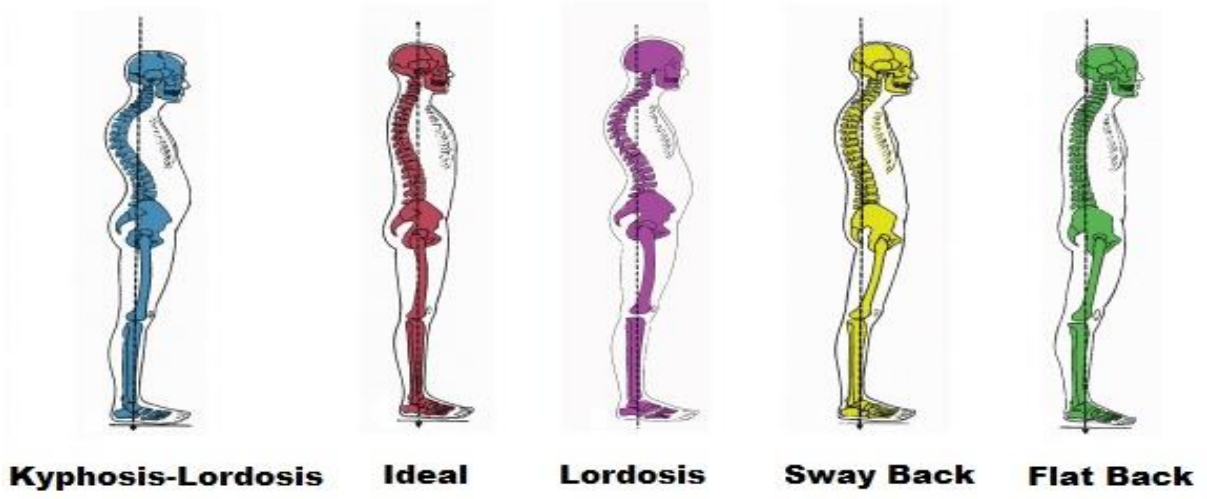

Figure 1 Different standing Postures[9]

There are 3 principles for analyses of postural control.

1.1.1 Quantitative and Qualitative Analyses Postural stability management are often quantitatively thought of by activity the movement of the centre of mass (COM),the centre of gravity(COG), the centre of foot pressure (COP), and body segments however additionally by activity electromyography activities and evaluations of the contribution of various sensory

data. The chemical analysis consists of describing however Postural stability management is organized in relevancy the mechanical and neuroscience aspects[10].

1.1.2 Postural Performance Postural control is characterised in terms of performance in keeping with the Postural stability condition into account. Postural performance refers to the flexibility to keep up body balance in difficult postural conditions (e.g., a stance classed as a gymnastic exercise, monopedal dynamic stance) and therefore avoiding Postural stability imbalance and falls. Postural performance may also characterize the flexibility to attenuate body sway in additional typical postural conditions (e.g., bipedal quiet stance)[10].

1.1.3 Postural Strategy it is outlined on the premise of the spatial and temporal organization of various body segments as well because the extent and order of enlisting of various muscles activated. The various sensory sensors concerned in postural regulation as well because the weight of various sensory data and/or the advantageous involvement of various neuronal loops also can contribute to explain postural strategy[10].

Chapter 2 State of the art

There are some mechanical and optical systems described which was used in background related to the postural stability measurement in soldiers, adults and elder people:-

2.1 Kistler 9286a, Force Plate

In a previous studies according to article the addition of body armour diminishes dynamic postural stability in military soldiers[4] to examine the consequences of armour on dynamic Postural stability throughout single-leg jump landings. Thirty-six 101st Division (Air Assault) troopers performed single-leg jump landings within the anterior direction with and while not carrying armour. The dynamic Postural stability index and also the individual stability indices (medial–lateral stability index, anterior–posterior stability index, and vertical stability index) were calculated for every condition. Paired sample t-tests were performed to see variations between conditions. Important variations existed for the medial–lateral stability index, anterior–posterior stability index, vertical stability index, and dynamic postural stability index. The addition of armour resulted in diminished dynamic Postural stability, which may end in augmented lower extremity injuries. Coaching programs ought to address the altered dynamic Postural stability while carrying armour in tries to push variations which will end in safer performance throughout dynamic tasks. In the result of study found out that the addition of a minimum load like armour results in diminished dynamic Postural stability as proved by increases in MLSI, APSI, VSI, and DPSI. Altered dynamic postural stability might end in a rise in lower extremity musculoskeletal injuries. Owing to the injurious effects, Body armour has on dynamic Postural stability, future analysis is bonded to develop physical coaching programs to push adaptations which will end in safer performance throughout loadbearing dynamic tasks whereas not increasing system injury rates.

The study in which Thirty-six subjects (male = thirty two, feminine = 4) were recruited from the military 101st mobile Division (Air Assault) to participate during this study. To participate, subjects should have been eighteen to forty five years recent from the 101st, with no history of concussion or delicate head injury within the previous year, no higher extremity, lower extremity, or back musculoskeletal pathology within the past three months that would have an effect on the flexibility to perform the specified tests, no history of neurological or balance disorders, and not taking any medications that would disrupt balance or. To boot, all subjects were cleared for active duty with none recent prescribed duty restrictions. Approval for this study was obtained from the University of Pittsburgh's Institutional Review Board,

EisenhowerArmyMedicalCenter,ClinicalInvestigationRegulatoryOffice,andtheHumanResearch Protection Office as half of an in progress research that specialize in injury prevention and performance improvement within the 101st mobile Division (Air Assault). All testing was conducted at our Human Performance research lab, Fort Campbell, Kentucky, a foreign analysis facility operated by the Neuromuscular Research Laboratory, University of Pittsburgh. Subjects were positioned 40% of their body height removed from the sting of a force plate and a thirty cm hurdle was placed at the centre between the beginning position and also the force plate. Subjects were tutored to leap within the anterior direction employing a bipedal omit the hurdle and to land on the force plate with solely the dominant leg, stabilize as quickly as doable, place their hands on their hips once stabilised, and stay still for ten s whereas wanting forward. Higher extremity movement was unrestricted throughout the jump; but, once subjects were stabilised they were asked to quickly place their hands on their hips. Subjects were allowed 3 observe trials for every condition to become conversant in the single-leg jump Downloaded landing task. Following the observe trials, subjects completed the take a look at trials. A 1-minute pause was provided between trials to forestall fatigue. Trials were discarded and continual if subjects didn't omit or came in reality with the hurdle, got wind of landing or if the non-dominant leg came in reality with the dominant leg or the bottom round the force plate. All subjects were ready to complete the task. All of the themes performed the task without armour first. a complete of 3 fortunate trials were collected for every condition (no-load and load) and used for information analysis[4].

Figure 2 Portable Multicomponent Force Plate Type 9286AA[11]

2.2 Biodex System

The system used for stability evaluation was useful The Biodex Balance System uses a microprocessor-based mechanism to regulate the steadiness of a suspended circular force plate. The force platform incorporates a most of 20° tilt in any direction once utterly un-stabilized and determines a participant's stability supported the variance of the platform from centre throughout a given task employing a sampling rate of one hundred Hertz[5][12]

The postural Stability test emphasizes a patient's ability to keep up centre of balance. The Score of patients on this test assesses deviations from centre, so a lower score is additional desirable than a higher score, the Biodex Balance System Mount Rushmore State additionally serves as a valuable balance analysis and balance coaching device to reinforce kinaesthetic abilities which will give some degree of compensation for impaired proprioceptive reflex mechanisms following injury. Using the special device, clinicians can assess neuromuscular control by quantifying the power to take care of dynamic bilateral and unilateral postural stability on a static or unstable surface. [12].

Figure 3 Biodex Balance System [12]

Figure 4 NeuroCom SMART Balance Master[13]

2.3 NeuroCom Smart Balance Master

The NeuroCom sensible Balance Master shown in figure above assesses dynamic Postural stability with the Limits of stability (LOS) take a look at. The device sampled at a frequency of a hundred cycle employing a 2–force plate structure connected by a pin joint within the vertical centre of the anterior-posterior centre line of every plate, with four electrical devices orientating vertically and one transducer orientating horizontally. During the LOS, the NeuroCom force plate remains mounted[5][14]

In the review of the study by Pickerill et al.All participants reportable to the sports medicine Laboratory for 2 testing sessions one week apart. Demographic knowledge were collected from all volunteers before testing to work out the overall characteristics of the sample population. A randomisation table was used to assign twelve participants to test dynamic LOS (DLOS) on the Biodex Balance System at the primary test session, whereas eleven participants began the study by testing LOS on the NeuroCom good Balance Master. The reverse check order was used throughout the second testing session for all volunteers. At every testing session, participants were provided verbal instruction and three to five minutes of apply with every device before testing. All were barefoot and performed two trials of the LOS on every device separated by five minutes, rested for about ten minutes, and so performed two trials on the opposite device, also separated by five minutes of rest[5][15].

2.4 Microsoft Kinect Sensor

According to the research from Wen-June Wang et al.[16]defines several image process techniques with the depth pictures captured by a Kinect device to with success acknowledge the 5 distinct human postures of sitting, standing, stooping, kneeling, and lying, The planned recognition procedure 1st uses back- ground subtraction on the depth image to extract a silhouette contour of an individual's. Then, a horizontal projection of the silhouette contour is utilized to determine whether or not the human is move. If the figure isn't move, the star skeleton technique is applied to the silhouette contour to get its feature points. We will then use the feature points along with the centre of gravity to calculate the feature vectors and depth values of the body. Next, we have a tendency to input the feature vectors and therefore the depth values into a pre-trained LVQ (learning vector quantization) neural network; the outputs of this may confirm the postures standing, stooping, and lying. Lastly, if associate degree output indicates sitting or standing, one any, similar feature identification technique is required to verify this output. Supported the results of the many experiments, victimisation the planned methodology, the speed of triple-crown recognition is above ninety seven within the take a look at knowledge, albeit the topics of the experiments might not are facing the Kinect sensing element and will have had completely different statures. The planned methodology is known as a “hybrid recognition method”, as many techniques square measure combined so as to attain a really high recognition rate paired with a really short process time. The study done by Wen-June Wang et al. works like a new posture recognition technique is proposed. The tactic uses solely 2 devices to realize its function: a laptop personal computer and a Kinect detector. The Kinect detector consists of a depth detector, an RGB camera, a multi- array electro-acoustic transducer and a motorized tilt. The depth detector consists of an infrared ray electrode and a monochrome CMOS detector to capture depth pictures with a resolution of 320×240 pixels; the RGB camera is employed to capture colour pictures with a resolution of 640×480 pixels. The multi-array microphone is used to receive the sound signal, however it'll not be utilized in this study. The motorized tilt will alter the Kinect sensor’s elevation angle. The USB port is employed for communication between the laptop personal computer and also the Kinect detector. The laptop personal computer is an Intel i5-520 running at 2.4GHz with 4G bytes DRAM. The image process techniques used cover the horizontal and vertical projection, star skeleton, and Learning Vector Quantization neural network and image process techniques. 5 human postures, standing, sitting, stooping, kneeling, and lying, are recognized. The rationale for choosing these 5 postures is that they're the final and basic postures of the human kind.

Conclusions regarding alternative postures not mentioned here could also be extrapolated from the gained results.

Study contributes to analysis regarding automatic home care systems. Senior people that live alone will usually have the benefit of a robot to supply home care services. These robots should have a capability to acknowledge the person's postures in normal and dangerous situations, so as to send accurate reports to the care centre[16].

On other hand research of assessment postural control done by Ross a Clark et al. says That assessment of postural management is often manage in laboratory and clinical settings for a large range of pathologies, and therefore the ability to perform well on several of those tests has been connected to factors like physical function and falls risk. Measurement tools for assessing postural control range from simple, time-based assessments through to full-body kinematic and kinetic examinations. In relevancy clinic-based assessments, 3 of the foremost ordinarily performed postural control tests are single leg stance time, the Berg Balance Scale and timed up and go. Though the Berg Balance Scale includes visually determined assessments of quality of movement, a standard component of those tests is their limitation to either timing or reach-based outcome measures. Whereas providing helpful info to the practician, they're vulnerable to ceiling effects and commonly cannot accurately quantify the postural control strategies being used by the patient[17]. Adding additional advanced information assortment and analysis tools like force platforms and 3 dimensional camera systems permits for identical tests to be analysed in finer detail. As an example, additionally to measuring hand displacement throughout a functional reach test, a 3D camera system will be incorporated into the testing protocol to measure spatiotemporal factors like trajectories of movement, which have been shown to discriminate between neurological and healthy populations[18].

They did the experiment in which Subjects were needed to wear tight shorts and an upper body garment that allowed for placement of reflective markers in accordance with the full-body plug-in-gait marker set. This enclosed markers placed on the top, arms, wrists, hands, trunk, pelvis, legs and feet, and has been outlined very well antecedently, getting the positions of those markers and modelling of the joint angles was performed using VICON Nexus V1.5.2 acquiring image data from a twelve camera VICON mx motion analysis system. This was deemed our benchmark reference kinematic data[17].

The three postural management tests were performed so as of lateral reach, forward reach then single leg standing balance. The reach tests were performed with identical directions, with the

topic suggested to: **1**: abduct the shoulder till the arm was parallel to the ground whereas keeping the arm straight and hold this position for about 2 seconds, **2**: reach as so much out as potential within the respective axis of testing, whereas keeping each feet on the ground, and hold this position for about 2 seconds, and **3:** come to the beginning position. For the one leg, eyes closed standing balance check the topics performed constant protocol delineate antecedently. Specifically, this test needed the topic to stand as still as doable on their preferred limb for 15 s while keeping their eyes closed. All tests were performed thrice, with the primary 2 trials utilised for data analysis and also the third trial solely employed in the case of a data assortment error in either system, In the results they got, the measurements from the Microsoft KinectTM and 3D camera strategies were comparable in terms of absolute and relative test–retest dependability (ICC difference zero.16; ratio CV difference 11.6%), with pairwise comparison of intraclass correlation coefficient values showing no important variations between devices (95%bootstrap confidence intervals enclosed zero). The mean results for every system, Specific estimates from the ordinary least products regression analyses. The Microsoft KinectTM technique showed wonderful concurrent validity with the 3D camera technique, with the Pearson's R-values >0.90 for the bulk of measurements. The OLP analyses showed proportional biases for outcome measures related to the pelvis and sternum[17].

2.5 Nintendo Wii Balance Board

In the study done by Kian Merchant-Borna et al.[19] Test Balance and Cognition. During balance testing they used the Balance Error Scoring System and Wii Balance Board to assess balance. Every BESS assessment consists of three stances (double legged, single legged, and tandem) in a pair of conditions (firm surface and foam surface) that were performed with the eyes closed for twenty seconds per stance[20]. A trained member of the study staff followed the quality procedures for administering the BESS. All stances were discovered, and errors were documented. In Cognitions the Impact provides a well-validated live of neurocognitive perform which will be plagued by concussion and includes the subsequent sub-components: visual and verbal memory, visual motor speed, interval, and impulse management. It conjointly measures 22 post-concussive symptoms and provides an overall index of cognitive potency supported the scores from all domains[21]. We administered Impact at baseline and at days three and seven post-concussion. Athletes weren't group take a tested for the Impact however rather were schooled to complete the test on a desktop computer during a quiet space. They were unsupervised by study staff or athletic trainers while completing the test.

The ways used to perceive the postural system and measure standing balance have evolved over time. Early studies targeted on abnormalities in postural sway as an indicator of balance disorders, and so later studies progressed to a lot of advanced laboratory testing of responses underneath varied conditions. By the middle 1980's practical tests of balance began to become more distinguished[22].

Due to the quality of the postural system, balance are often evaluated at both a functional and a physiological level. The functional level can be additional directly assessed by functional performance tests of reach and quality. The physiological level includes measuring the contribution of sensory, motor and effector parts. Underneath static conditions the postural control system could compensate when disorders occur whereas, throughout dynamic conditions, compensation is sometimes delayed or insufficient[23].

Balance assessment tests should attempt to simulate dynamic conditions in order to stress the postural control system fully and reveal the presence of a balance disorder[24].

One of the test which is used for known as The Fugl-Meyer test contains six sections that assesses the subject's independence by evaluating their joint movement, joint pain, higher extremity motor control, lower extremity motor control, balance and sensation. A numerical worth is obtained for every of the activities within the sections for those performed in and out

of action. The section for evaluating balance contains 3 tests for assessing sitting balance and four tests for assessing standing balance, these tasks are ranked using a 3-point ordinal scale. This test provides a comprehensive qualitative analysis of useful balance and is often used for assessing subject's World Health Organization have suffered a stroke or subjects with balance disorders as a results of neurologic injury, like Parkinson's disease. There are no reported studies that have investigated the reliableness of this test[25].

2.6 Vicon Motion Capture System

Initially developed for gait analysis, robotics applications like UAVs (Unmanned Aerial Vehicle) extensively use Vicon systems. Worldwide varied Vicon equipped arenas exist like the arena represented in[26]. Studies on quadrotor UAVs use Vicon equipped arenas for functions like ground truth for positioning[27][28][29], 3D reconstruction or real-time management given the position calculable by the motion capture system. Marker positions are available at frequencies larger than hundred hertz. Vicon is one of the key players in optoelectronic motion capture systems supported markers. The trademark is commonly used as a proprietary eponym for optoelectronic motion capture systems. Other manufacturers like Motion Analysis ,Optitrack or Qualisys additionally exist[30].

Motion capture is that the method of recording the movement of objects or people, the structure of the system shown below in figure. The technology originated within the life science marketplace for gait analysis however is currently used widely by VFX studios, sports therapists, neuroscientists, and for validation and control of computer vision and artificial intelligence[31].

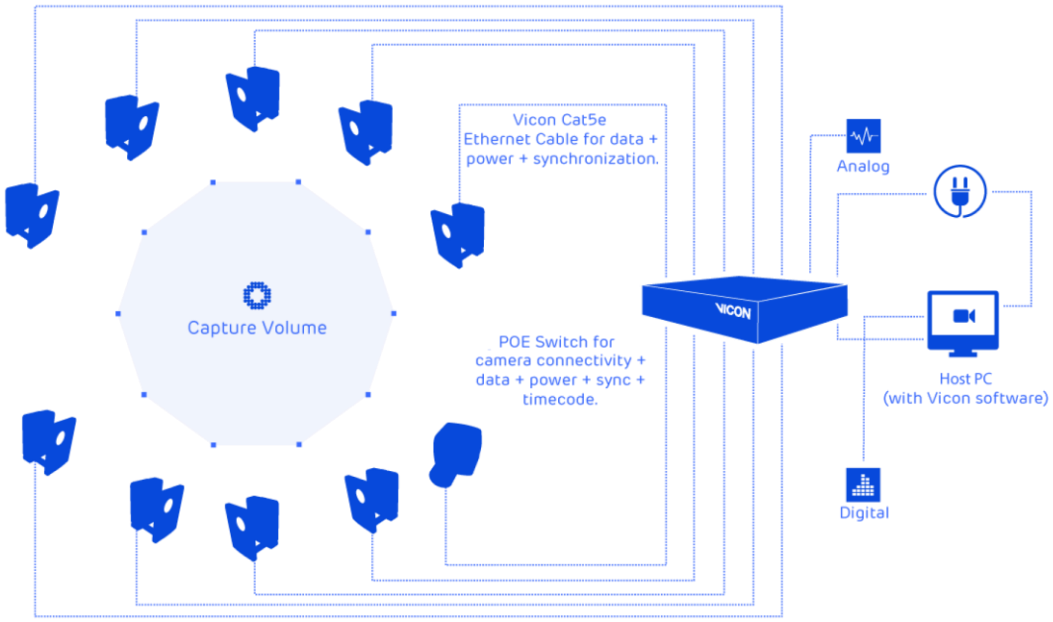

Figure 5 Structure of Vicon motion capture system[32]

Yang et al..[33] Have evaluated the positioning performance in 3D with a numerical control drilling machine. The expected positioning precision is given as 20 µm. various samples are taken in a space comparable to 400 × 300 × 300 mm^3 . Four marker sizes were investigated. They found that the marker size does not impact the positioning performance. The key difference is explained by the Vicon camera sensor resolution. The performance is evaluated from 20 different positions. Positioning data is collected for 1 second at each location with a motion capture device running at 100 Hz. The metric used is the mean absolute error over all samples. The position-wise performance is not investigated[30].

Studies done by Manecy et al. Shows the 3D positioning performance in a Vicon equipped arena used for UAVs. The arena is equipped with 17 cameras and represents a space of 6 * 6 * 8 mm^3. They did not exactly investigate the Vicon accuracy as no other ground truth setup was used. Markers were manually placed in the arena. The performance metric actually corresponds to the positioning measurement variability. This work demonstrates that the positioning variability is less than 1.5 mm[26].

2.7 Optitrack Motion Capture System

The spreading of motion analysis means additionally to market-leading overpriced high-end systems, like Vicon, cheaper camera systems appeared that weren't specifically meant for scientific functions, however sneaked in scientific motion labs. One such complete is Optitrack that was applied to the field of biomechanics from animation motion capture. Its main applications presently embody video game (Virtual Reality), robotics, movement sciences and animations. it's taken time for Optitrack to become a scientifically accepted and used system as motion labs already trust their own well-established high-end motion capture systems. The spreading of cheaper systems additionally needs validation studies that compare the accuracy of recent systems with scientific gold commonplace systems, representing an approach that researchers can relate to. Different possible vital technical aspects of adequacy during a specific application are capture volume, minimum detectable marker size, frequency and resolution of the motion capture system[34].The huge structure which need for measurements with Optitrack system shown below in the figure[35].

Figure 6 Example of the structure built with Optitrack system

Table of systems

In the table shown below contains some general systems of which can be helpful to measure postural stability of some important parameters such as COG, COP.

Table contains both Mechanical and optical motion capture systems.

Table 1 List of General Systems and methods used to evaluate postural Stability

Posture	Test(System)	Variable	Parameter	Application	Citation
Single-leg jump	Kistler 9286A, force plate	1. Anterior–posterior (APSI) 2. Medial–lateral (MLSI) 3. Vertical (VSI) 4.DPSI(dynamic postural stability index)	Mechanical force	Collect Ground reaction force data for dynamic postural stability	[4] [36]
Standing	Biodex Balance System	Directional control test time	Centre of Pressure, Angular motion	Stability of subject	[5] [12]
Standing	NeuroCom Smart Balance Master	Directional control Endpoint excursion Movement velocity	Angular motion Linear stability,	dynamic postural stability	[5] [14]
standing, sitting, stooping, kneeling, and lying	Microsoft Kinect sensor	Range of motion	Angle of motion	To measure timing and range of large movement in posture	[16] [37]
Standing	Nintendo Wii balance board	Velocity of medial lateral(VML) and velocity of anterior posterior(VAP)	Centre of pressure	Measure centre of pressure	[19]
Standing	The Functional Reach test(ability to reach as far	Inter-rater reliability	Centre of gravity	This test will provides quantitative dynamic information about the subject's ability to maintain standing	[38][39] [40]

	forward as possible without taking a step forward or falling)			balance, to know Parkinson's disease.	
Sitting and standing	The Fugl-Meyer Test	-	-	This test provides a comprehensive qualitative evaluation of functional balance, evaluate changes in motor impairment following stroke	[40] [41][25]
Standing (displacement of the waist)	Potentiometric Displacement Transducer	anterior-posterior sway	Velocity from rotational motion	This technique has been used to evaluate the sway patterns of healthy volunteers	[40]
Motion Capture	vicon	-	Angular motion	It is used by VFX studios, sports therapists, neuroscientists, and for validation and control of computer vision and robotics.	[32]
Motion capture	Optitrack	-	Angular motion	This system is often use in movement science, virtual reality, animation and robotics studies, biomechanics.	[34][35]

Chapter 3 Methodology

The system works on the anatomical point of the body and the sensors are on this anatomical points which is shown below in the figure.

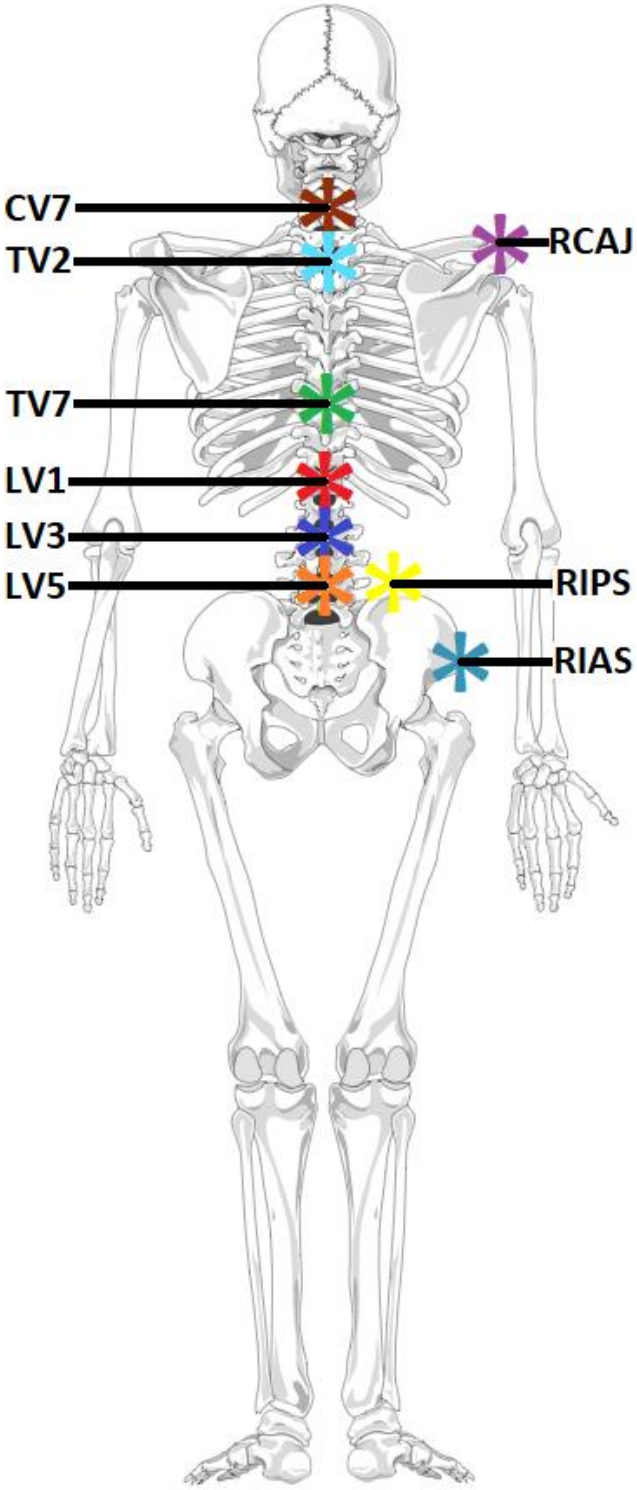

Figure 7 Different anatomical points on the body where sensors where placed

The brief description of the anatomical points are according to below information.

The vertebral column, also known as the vertebral column, spine, or backbone, in vertebrate animals is the versatile column extending from neck to tail, fabricated from series of bones, the vertebrae. In human vertebral column, there are thirty three vertebrae divided into cervical (C1-C7), thoracic (T1- T12), lumbar (L1-L5), sacral (S1-S5) and coccyx (3-5 segments).

1. CV - Cervical vertebrae (C1–C7)
2. TV - Thoracic vertebrae (T1–T12)
3. LV - Lumbar vertebrae (L1–L5)
4. RCAJ - Right acromion
5. RIPS -Right posterior superior iliac spine
6. RIAS - Right anterior superior iliac spine

It is a section of the axial skeleton and protects the neural structures and internal organs. Its two columns, an anterior column that could be a solid column of bone bodies and is compression-resistant and a posterior column which is a hollow column of neural canal and is tension-resistant. It has facets that resist rotation and anterior displacement. The road of gravity of the physique passes through the auricle of the ear, odontoid process, body of C7, anterior to thoracic spine, posterior to L3, and middle limb heads. The spine is that the shaft bearing the load of the top, shoulders and thorax. The higher body weight is then distributed to the lower extremities through the sacrum and pelvis. This reduces the quantity of labour needed by spinal muscles and may eliminate muscle fatigue and back pain. To attain these functions, the spine should have: Resistance to axial loading forces accomplished by kyphotic and lordotic sagittal curves and accumulated mass of every vertebra from C1 to the sacrum. Elasticity accomplished by alternating swayback (cervical and lumbar) and humpbacked (thoracic and sacral) curves and multiple motion segments[42].

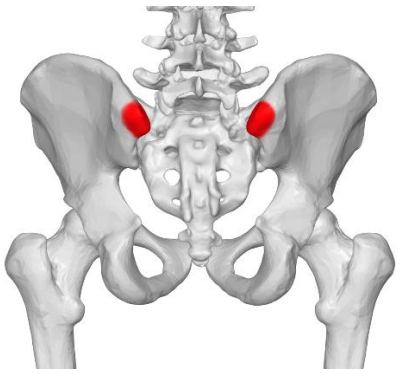

Figure 8 RIPS marked in Red in the hip skeletal structure[43]

Figure 9 RIAS Highlighted in red spot in hip skeletal structure[44]

(RIAS, RIPS) The ilium is the uppermost and largest part of the hip bone in the body which is divisible into two parts, the body and the wing the separation which is indicated on to the top surface by a curved line and the actuate line, and on the external surface by the margin of the acetabulum[45].

The posterior inferior iliac spine is an anatomical landmark that describes a bony spine, or projection, at the posterior and inferior surface of the iliac bone, the anterior superior iliac spine is a bony projection of the iliac bone and an important landmark of surface anatomy.

RCAJ, In the Human Body acromion is a bony process on the scapula. Together with the coracoid process it extends laterally over the shoulder joint. The acromion is a prolongation of the scapular spine, and hooks over anteriorly. It articulates with the clavicle to form the acromioclavicular joint.

3.1 Subjects

Thirty young soldiers from different groups like Airborne Troops (chromium) (age: 27.6 ± 6.6 years), Castle Guard (Lány) (age: 24.2 ±2.4 years), Mechanized Infantry (Žatec) (age: 29.8 ±7.7 years) with no background of neurological disorder or medication which can cause effect on their postural evaluation volunteered to participate. The weight and height are average it cannot disclosed because of security reasons of the participants. The study was done under approval of CASRI institute of physical education of sports in Prague.

The information about different groups are as below the Participants are anonymised but the basic details and their duties are as described below.

Airborne Troops (Chrudim) is a light airborne battalion of the commando sort, whereas within the Army of the Czech Republic it's the sole unit of this kind. The battalion represents the most expeditionary force of the Czech Republic's Army with high strength. It's destined to hold out tactical tasks within the Czech Republic and on the far side, either separately or among the national and alliance forces. In combat, it's designed to eliminate the enemy's ability, specifically by quickly maneuvering and guiding moving and decisive action in varied sorts of operations, in any weather and in any terrain, and to fight within the depth of enemy assembly, The battalion is prepared for positioning alone or within the report of the brigade to perform tasks in combat and peaceful operations. This can be additionally mirrored in its commanding structure, divided into 3 basic parts: combat, combat support and logistics. The airborne Battalion is prepared to hold out a full spectrum of military operations, particularly striking character, and operations to support stability and facilitate the population in the Czech Republic, like strengthening the state border, guarding vital buildings or serving to the population in natural and humanitarian disasters. Above all, the battalion is trained and ready to[46]:

Tactical mobile landing

Fighting in settled and fortified areas

Fight in rugged terrain

Medicine, Overflows

Diversionary action, Combat patrolling in peace enforcement operations

Castle Guard (Lány) is an armed force unit of the of the Czech Republic directly subordinate to the Military workplace in the country and the President of the Czech Republic, the duties

assign to castle guards according to the details described on Ministry of Defence Czech republic website such as :

1. Performs external security tasks to protect the Prague Castle, provides its defence and performs external security and defence of facilities that the President and his guest quickly use;

2. Organises and performs military honours, primarily in official visits by different states' representatives and through the calls heads of diplomatic missions have with the President;

3. Should not be used for performance of different tasks than those outlined beneath conditions above, except the approval of the President.

Mechanized infantry (Žatec) are the land forces of Czech Republic who's designed and train task forces groups which can solve tactical and operation-tactical tasks on the Czech territory and further on, and to meet alternative tasks within the Czech Republic in accordance with domestic legislation as described on the ministry of defence Czech Republic website[47].

3.2 Equipment

The transportable system which is used to measure the data was made up of combination of Microsoft Kinect camera version1 (MKV1), Microsoft camera version2 (MKV2) and two Nintendo Wii fit balance board, according to the study of Validity of the Microsoft Kinect for assessment of postural control. Gait & posture done proposed by Clark R et al. says that MKV1 has the potential to be utilized in clinical applications, particularly within the kind Of an inexpensive screening methodology for persons at risk of falling[17]. MKV2 has higher accuracy in depth variable pictures compared to MKV1 and, above all, its accuracy is constant in measurement range. MKV1 accuracy decreases exponentially with distance from the object, on the opposite hand, MKV1 has higher accuracy just in case of flat objects[48].both the cameras frame rate is 30HZ[49][50].

The use of combine of NWBB force platforms allows centre of pressure (COP) and centre of gravity (COG) measurements, whereas additionally permitting variability in positioning of the platforms relative to each other within the horizontal and vertical planes, which alter the creation of simulation of various situations, like running, climbing up stairs, etc. The Nintendo Wii Balance Board has the potential to become a useful tool in clinical assessments of equilibrium. Although, it cannot absolutely replace the laboratory force platforms since it's able to perform measurements solely on the vertical axis and not along the horizontal axis, affecting the evaluation of COP, the measurement uncertainty between the platforms is 9.1 N and 4.1 mm COP. The measurement uncertainty of one platform in case of repeated measurement is 4.5 N and 1.5 mm COP at a sampling frequency of approximately 100 Hz[51][49]. Minimum sampling frequency required for the determination of COP is approx. 40 Hz[52].

The system was designed with reference to ease of transportation and therefore the Ability to measure static postural stability, particularly of spine parameters and also the relative Position of the pelvis and chest in the sagittal plane. Those parameters additionally play a role in the transition to erect posture in childhood and are the idea of so-called neuromuscular equalization[49].

According to the article by Hejda J et al. The total price of the transportable systems which used for postural stability evaluation without computer technology is about approx. 350 USD which include 2x NWBB, MKV1, MKV2, Kinect V2 PC adapter. All measurements and data processing were performed in MATLAB software 2018a version[49].

Microsoft Kinect camera

As briefly described in article by Hejda J et al. Designers of the transportable system ensure that the positioning of MKV1 and MKV2 should be proper towards the anatomical points so they used custom made lightweight aluminium profile construction which shown below in figure 9, this design allows both camera in vertical position with option to adjust height which allows it to measure subject at different heights, with the lightweight construction they also combine the custom made transportation case which allows all the equipment free movement[49].

Figure 10 Lightweight aluminium construction that ensure the correct camera positioning.

In the article of the comparison between MKV1 and MKV2 author the two device in identical environments and in identical experiments in order to draw repeatable conclusions on

preciseness and accuracy of the captured depth pictures. To the most effective of the knowledge the accuracy in terms of a metrically correct depth estimation was not assessed to this point. Progressive papers measure the distance from the camera case to a seen object with a tape or a laser, but, depth is defined from the camera centre to an object, that is tough to measure with their approaches. In the approach author tend to verify ground truth depth estimation for planar surfaces with a checkerboard. This delivers correct results and allows easy repetition for different researcher using their own Kinect sensors or even different cameras. The experiments enables to directly compare the results for the two devices[48].

Figure 11 Microsoft Kinect camera version1 [43], Microsoft Kinect camera version2 [44]

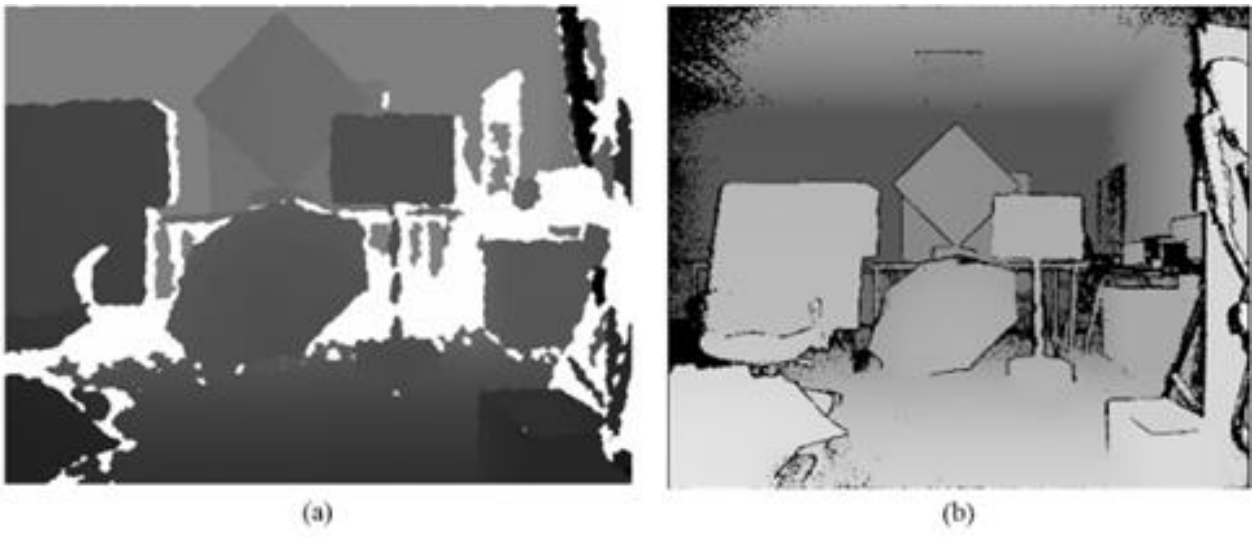

Figure 12 Depth image comparison between Kinect v1 and v2 (a) Depth-image of Kinect MKV1

(b) Depth-image of Kinect MKV2[53]

Microsoft Kinect Version1:

In the transportable system designed by Hejda J et al. the camera aimed for right lateral projection, and the MKV1 was used in RGB mode settings. The MKV1 uses structured-light approach with a 320x240px depth sensing element permitting measurement between 1.8-3.5 m and 640x480px RGB camera with Field of view of 57° in horizontal and 43° in vertical direction. A standard USB 2.0 interface was used to connect to the computer. Kinect for Windows SDK 1.8 was installed in the Windows 10 setting and the “Image Acquisition Toolbox Support Package for Kinect for Windows Sensor” was installed in the MATLAB 2018a environment where data processed, and further more to evaluate the mutual position of the pelvis and chest within the lateral plane, anatomical points which is described above (RIAS, RIPS, RCAJ, TV7, SXS) were used. Green markers of 4 cm diameter were connected to the RIAS, RIPS, TV7, SXS anatomical positions and a green 2.5 cm marker was connected to the RCAJ anatomical position with relevancy visibility and possible marker coverage[49].

In the studies RGB picture came by the “getsnapshot" function Figure 13A was regenerate into the lab colour space using the "rgb2lab"function. The through empirical observation found threshold was afterward applied to lab space’s A channel Figure 13B, to cut back noise and unwanted image artifacts, the morphological gap and closing with structural component “disk” with 1px radius provided by the “strel” function was applied on the resulting image exploitation “imopen” and “imclose” functions. 5 contiguous regions with the largest area determined by the “regionprops” function with the "area" parameter were labelled for sure markers. To see regions’ centers, the “regionprops” function with the "centroid" parameter was used. Processed image with labelled markers and determined angles between them is pictured on Figure 14[49].

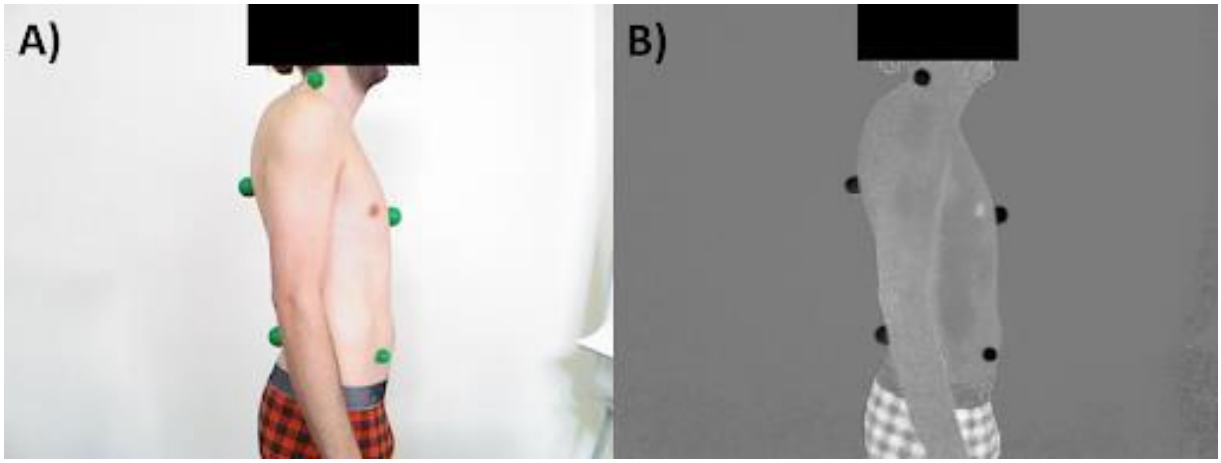

Figure 13 Kinect camera 1 (a) original image,(b) lab channel A image

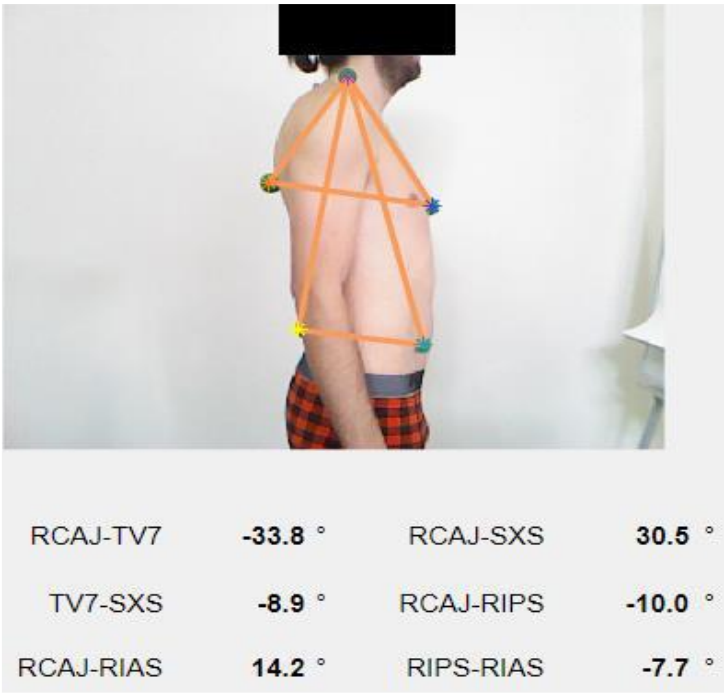

Figure 14 Determined angles between anatomical points assign for evaluation

Microsoft Kinect version2:

A Microsoft Kinect version2 was used in depth mode as a camera for dorsal projection. The camera uses Time-of-flight (TOF) approach with a 512x424px depth sensor has ability to measure distance between 1.3-3.5 meters and a 1920x1080px RGB camera with horizontal FOV of 70° and vertical Field Of View of 60°[54]. For Kinect V2 computer adapter is required for a connection to computer through the standard USB 3.0 interface. Kinect sensor for Windows SDK 2.0 was installed for the necessary communication in the Windows 10 setting, the anatomical points CV7, TV2, TV7, LV1, LV3, LV5(as described above in detail) were used for calculation of spine parameters with mutual position of individual vertebrae. Standard reflective markers with a diameter of 1.5 cm appearing in the picture as regions with undefined depth were connected to these anatomical points in figure 15(a,b,c) present original depth map, underlying depth pixels and the reflective markers, then on another hand figure 16 serves image with markers and angles between the connections[49].

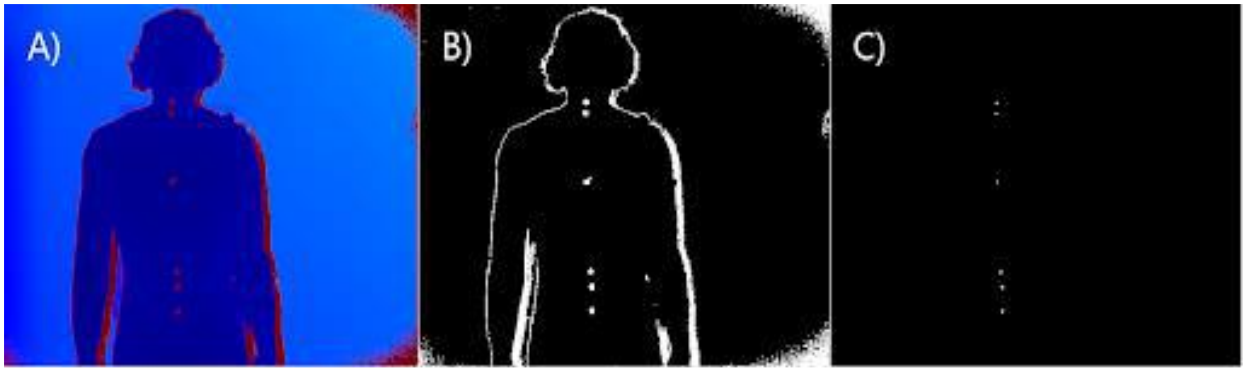

Figure 15 Identified (a) original image processed, (b) undefined image process,

c) Reflective image of markers on the anatomical points

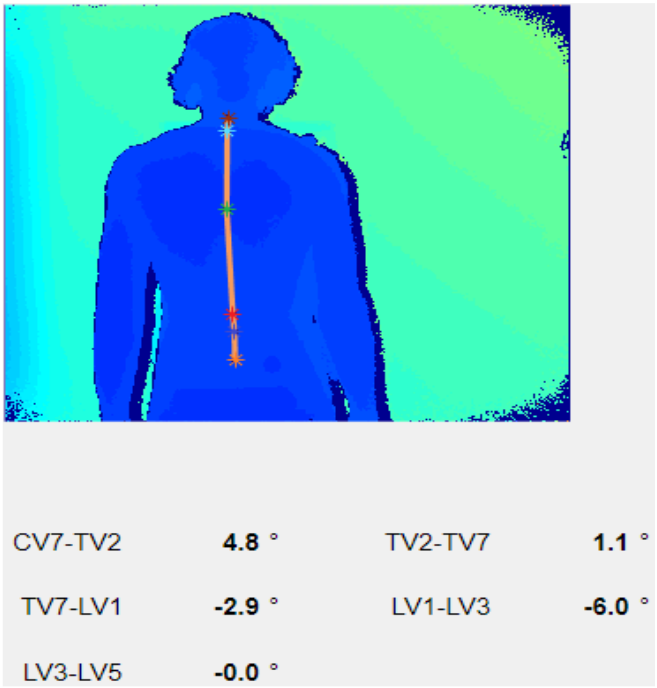

Figure 16 Identified markers from back camera serves angle between anatomical points

Nintendo Wii fit balance board

Clinical testing of balance ability is commonly measured with the smart balance master system (SBM), which needs a significant quantity of house and depends on the help of an expert. A modality diversion console acknowledged as the Nintendo Wii has gained quality in recent years. It integrates the Wii work balance board and balance detector devices into interactive games. The Wii work balance board is economical and simple to use. Therefore, we tend to designed a balance assessment device supported the Wii work balance board. This time period device includes the balance board, software, and info. It will show and calculate the gap of weight shifting. The aim of our study was to examine its dependability and validity compared to the SBM, and to gift the feasibility of the changed Wii work balance board a balance assessment[55]. The Wii tracks COP using internal parts kind of like laboratory-grade force platforms. The Wii has conjointly incontestable smart to excellent test-retest reliableness and wonderful coinciding validity compared with a laboratory-grade force platform, with nearly identical COP traces reported additionally, compared with scientific-grade force plates, the Wii has demonstrated higher validity and test-retest reliableness than the Balance Error Scoring System. Thus, the Wii is also a useful gizmo for assessing post-concussion balance impairments, given that force platforms have previously shown their utility. However, few researchers have quantified post-concussion balance symptoms employing a Wii, and no studies have included prospective knowledge, with pre injury and post-concussion balance assessments[19].

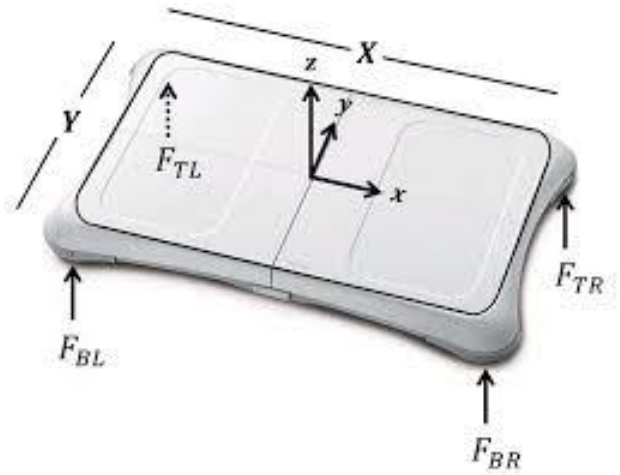

Figure 17 Nintendo Fit Wii balance board with x and y plane

(F=force, TR=Top Right, BR=Bottom Right, TL=Top left, BL=Bottom Left)[56]

The board is rectangular in form as seen in figure 16 and weighs 3.5 kilograms. It is capable of supporting up to 150 kg and is powered by four AA batteries granting 60 hours of operation. The board communicates using Bluetooth technology and is able to send info back at sixty signals per second. This different would require a laptop with an in-built Bluetooth association or the addition of an electronic device to receive the feedback furthermore as a software package program to run calculations[19]. This technique uses a pair of NWBB platforms to measure the COP beneath each feet and COG of the body. For connectivity, the "WiiLab" library, originally designed for Nintendo Wiimote drivers, was used. The connection is formed via Bluetooth. The library "Wii Lab" retrieves the output of the COP of the platform or the load of the individual force sensors placed within the corners of the platform. However, the values of individual sensors (BBVals) are four times over the proper value. This is probably due to a library calculation error and multiplication by the quantity of sensors. For this reason, the collected BBvals values were divided by 4, then used for the evaluation of the COP of platforms using the torque method [18] (equations 1-4) and COG for platforms that were placed next to each other (equations 5, 6). Values 433 and 238 utilized in the equations indicate the gap between platform sensors in millimetre. The value 77 is the distance between the sensors of adjacent platforms in millimetre. Index l is used for the left platform, r is for the right platform[49].

$$COP_{l,x} = -\left(\frac{77}{2}+\frac{238}{2}\right)+\frac{238}{2}\left(\frac{\sum_{i=1}^{2}\mathrm{BBVals_l}(i)-\sum_{i=3}^{4}\mathrm{BBVals_l}(i)}{\sum \mathrm{BBVals}_l}\right) \quad (1)$$

$$\mathrm{COP_{l,y}} = -\frac{433}{2}\left(\frac{\left(\mathrm{BBVals_l}(1)+\mathrm{BBVals_l}(3)\right)-\left(\mathrm{BBVals_l}(2)+\mathrm{BBVals_l}(4)\right)}{\sum \mathrm{BBVals_l}}\right) \quad (2)$$

$$COP_{r,x} = \left(\frac{77}{2}+\frac{238}{2}\right)+\frac{238}{2}\left(\frac{\sum_{i=1}^{2}\mathrm{BBVals_r}(i)-\sum_{i=3}^{4}\mathrm{BBVals_r}(i)}{\sum \mathrm{BBVals}_r}\right) \quad (3)$$

$$\mathrm{COP_{r,y}} = \frac{433}{2}\left(\frac{\left(\mathrm{BBVals_r}(1)+\mathrm{BBVals_r}(3)\right)-\left(\mathrm{BBVals_r}(2)+\mathrm{BBVals_r}(4)\right)}{\sum \mathrm{BBVals_r}}\right) \quad (4)$$

$$COG_x = \frac{\left(\frac{77}{2}+238\right)\left(\sum_{i=3}^{4}\mathrm{BBVals_r}(i)-\sum_{i=3}^{4}\mathrm{BBVals_l}(i)\right)+\frac{77}{2}\left(\sum_{i=1}^{2}\mathrm{BBVals_r}(i)-\sum_{i=1}^{2}\mathrm{BBVals_l}(i)\right)}{\sum \mathrm{BBVals_r}+\sum \mathrm{BBVals_l}} \quad (5)$$

$$\mathrm{COG_y} = \mathrm{COP_{r,y}} - COP_{l,y} \quad (6)$$

The Whole Transportable system are shown in figure below, the image is taken from the Design of a hybrid portable system for measuring the position of the spine, pelvis and centre of gravity of the body research done by Hejda J. et al.[49].

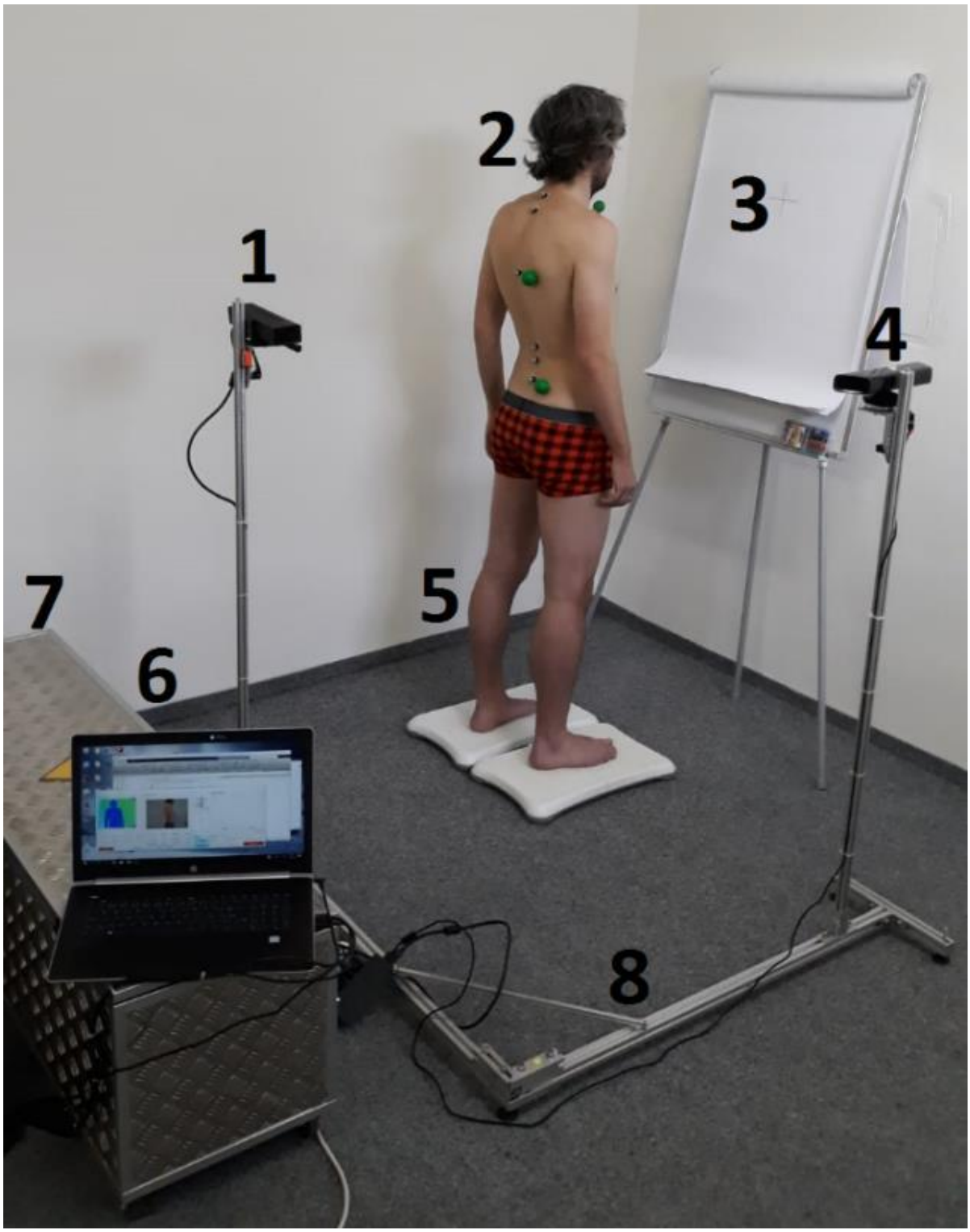

Figure 18 The Hybrid transportable system for measuring the position of the spine, pelvis and COG of the body (1 – MKV2, 2 – measured subject, 3 – point to fix the subject's view, 4 – MKV1, 5 – NWBB, 6 – laptop, 7 – transport box, 8 – camera mounting cons)

3.3 Software used for calculations

For data recording purposes a MATLAB graphical user interface application in the figure below has been designed by Hejda j. et al. used for putting in measurement and storing measured data into ".xlsx" format. For statistical processing, scripts for analysis of statistical parameters like mean, SD (standard deviation), median, quartile, range, etc., alongside the determination of 95th confidence ellipse were implemented.

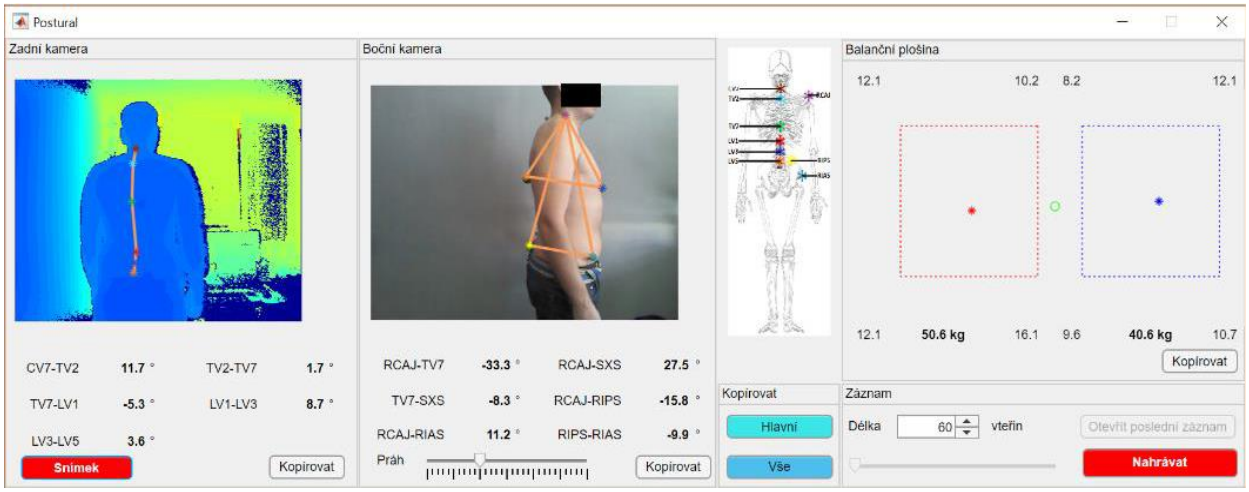

Figure 19 Application designed for data capturing in Matlab

3.4 Statistical method used for statistics Kruskal Wallis Test

For the comparison of over 2 independent samples the Kruskal-Wallis H test is a preferred procedure in several situations. However, the precise null and alternative hypotheses as well because the assumptions of this test don't appear to be very clear among behavioural scientists.

Suppose a particular test statistic S is suitable for testing the null hypothesis of identical population distributions. If S is significant at level α we can conclude that the distributions to be compared are completely different from each other. Fairly often we don't seem to be satisfied with solely such a general statement. We'd like additionally to grasp in what means are these distributions different. Do they have completely different means, medians, variances, this problem can be given by determining what alternative hypotheses are consistent for the S test statistic. A statistical test is named consistent for a given other to the null hypothesis if there for any level of significance α, when that alternative hypothesis is true, the probability of rejecting the false null hypothesis, for i.e. the power of the test, approaches 1 the sample size N on which the test relies approaches infinity. The consistency analysis of a test will reveal to

which alternatives this test is most sensitive as a result of if the sample size is massive, beneath these alternatives the probability of rejecting the false null hypothesis are the highest[57].

The null hypothesis;

$$H_o : \mu 1 = \mu 2 = \ldots = \mu k. \quad (1)$$

The Kruskal-Wallis test is the non-parametric analogue of a one-way ANOVA, that doesn't make assumptions about normality. Like most non-parametric tests, it's performed on the ranks of the measurement observations. It does, however, assume that the observations in every group come from populations with constant form of distribution, so if different groups have different| shapes, the Kruskal-Wallis test might give inaccurate results[58].

How the Kruskal-wallis Test works?

The Kruskal-Wallis test starts by substituting the rank within the overall data set for each measurement value. The small value in data gets a rank of 1, the second small gets a rank of 2, etc. Tied observations get average ranks, so if there were four identical values occupying the fifth, sixth, seventh and eighth smallest places, all would get a rank of 6.5. The total of the ranks ri is calculated for every group i (i = 1, 2, 3, 4... k) of size ni, then the test statistic H from is calculated, which basically represents the variance of the ranks among groups, with an adjustment for the quantity of ties. H is roughly $\chi 2$ distributed, with the degrees of freedom equal to the number of groups k- 1[58].

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1), \quad N = \sum_{i=1}^{k} n_i. \quad (2)$$

The differences in three groups are shown by the boxplot, A box plot is a standardized method of displaying the distribution of data based on a five number summary such as “minimum”,

first quartile which is Q1, median, third quartile which is Q3, and “maximum”. It will tell you about your outliers and what their values are. It can even tell that if the data is symmetrical, how tightly the data sorted, and if the way data will skewed, so before that it’s necessary to understand how to see boxplot below the figure describes how does boxplot represents the data[59]:

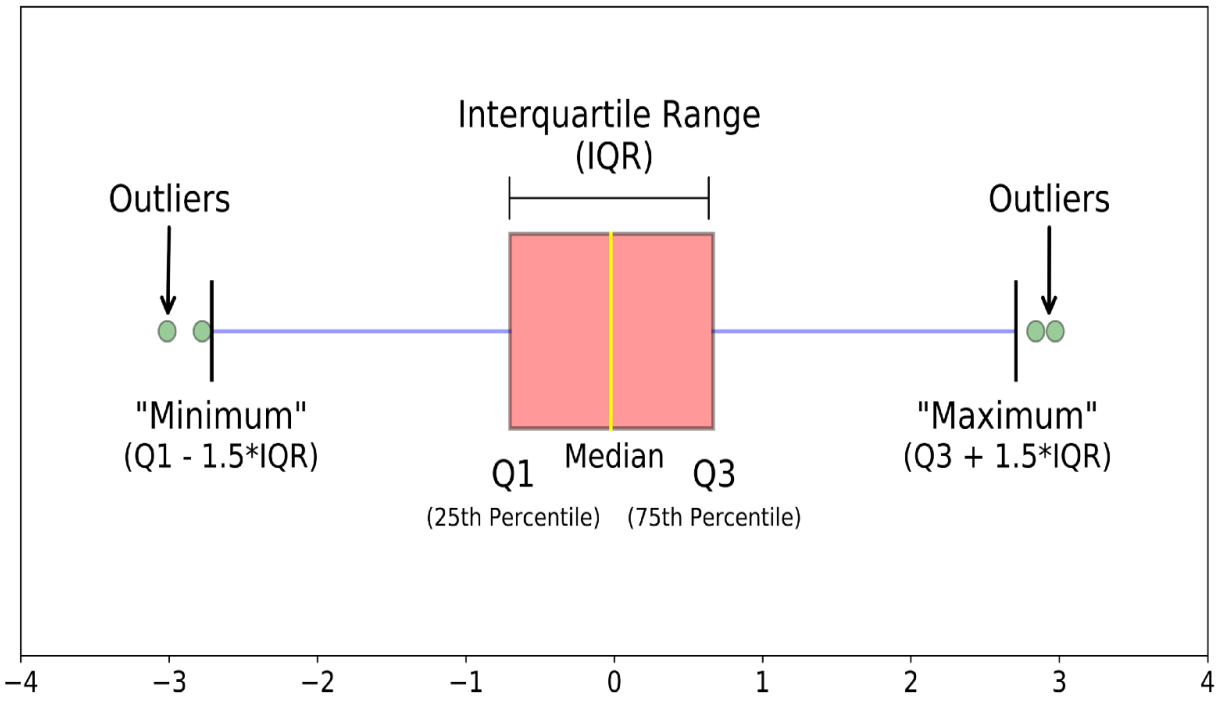

Figure 20 Details on How to see box plot (important parameters of boxplot)

An outlier is an observation which has numerically distant from the rest of the data. When reviewing a box plot, an outlier is outlined as a data point that's situated outside the fences (“whiskers”) of the box plot for example outside 1.5 times the interquartile range above the upper quartile and bellow the lower quartile.

Chapter 4 Results

For the statistical evaluation and check the hypothesis between the groups the software R is used, R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS.

The data obtained from the hybrid transportable system method and software like Centre of Pressure and Centre of Gravity are evaluated in the statistical method, the data processed in excel with calculation of mean values and also the Standard Deviation. Then the data in the form of .xlsx imported in the R software and then the Kruskal-Wallis test was performed.

The values of Centre of Gravity is as shown below in the appendix table (2, 3, and 4).

Upon the data above the Kruskal-Wallis test performed and with 95% family-wise confidence level the results are according to below;

For the COGX SD the **P value is 0.2259** and also for the COGY SD the **P value is 0.2288** so it means that the test is not rejecting the null hypothesis.

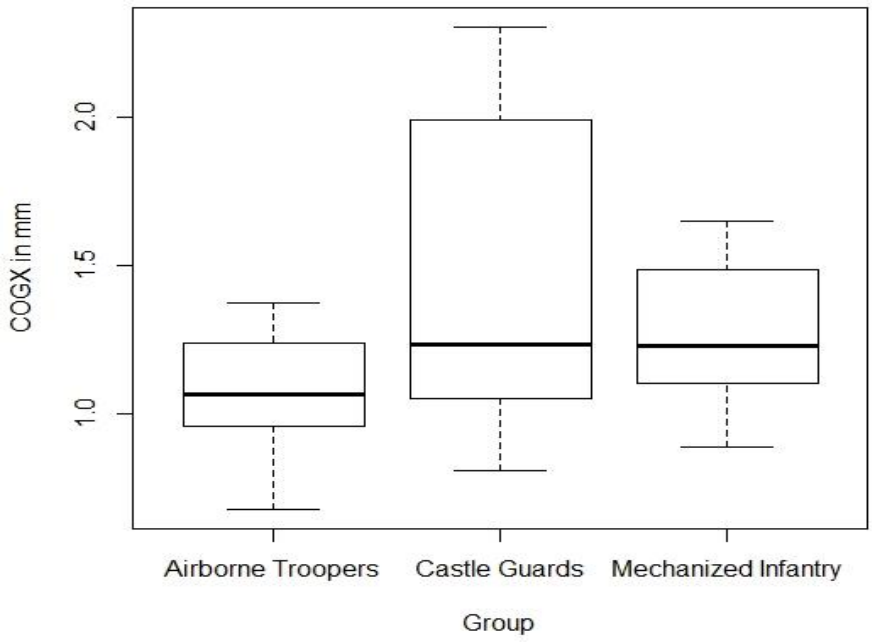

Figure 21 Box plot elaborate the statistical hypothesis of COGX SD between all three groups

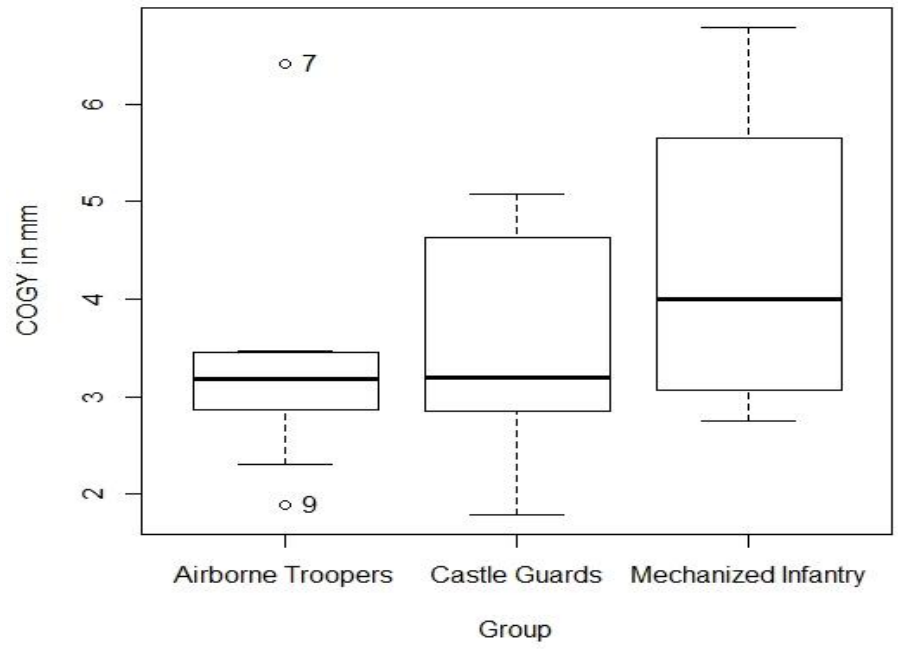

Figure 22 Box plot elaborate the statistical hypothesis of COGY SD between all three groups

The values of COPX, COPY for both left and right side which derived from the Hybrid transportable system for postural evaluation are shown in the appendix below. The results for COPX left side derived **P-value = 0.008347** it means the statistics are rejecting null hypothesis Where on other hand COPY left side **P-value = 0.1871** and it is not rejecting null hypothesis. For COPX right side has **P-value = 0.02903** so it is rejecting the null hypothesis.

And the **P-value** for COPY right side is **0.2101** so it's not rejecting null hypothesis, the box plots for all above results for COP are as below in figures,

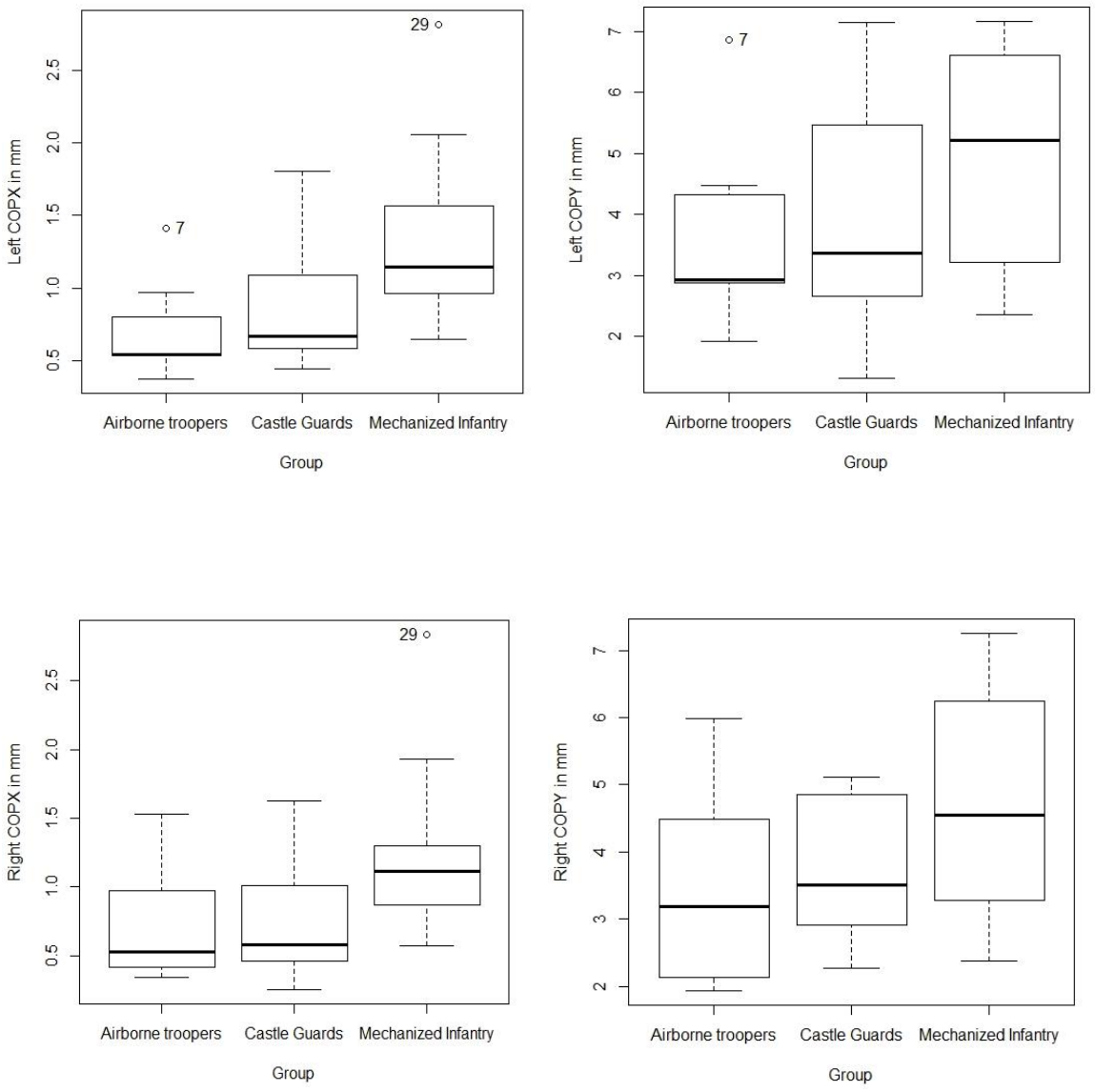

Figure 23 Boxplots for COP SD left &right side from X & Y axis in mm

Now after the results from COG and COP there is a results from different angles between anatomical points on the body.

The Results from the Kruskal-Wallis test for the angles between anatomical points are;

For Cv7Tv2 the P-value is 0.946, so it is not rejecting null hypothesis.

For Lv1Lv3 the P-value is 0.2894, so it is not rejecting null hypothesis.

For Lv3Lv5 the P-value is 0.1546, so it is not rejecting null hypothesis.

For RcajRias the P-value is 0.1791, so it is not rejecting null hypothesis.

FOR RCAJRIPS THE P-VALUE IS 0.04145, IT IS REJECTING NULL HYPOTHESIS.

FOR RCAJSXS THE P-VALUE IS 0.009231, IT IS REJECTING NULL HYPOTHESIS.

FOR RCAJTV7 THE P-VALUE IS 0.007243, IT IS REJECTING NULL HYPOTHESIS.

For RipsRias the P-value is 0.75, so it is not rejecting null hypothesis.

For Tv2Tv7 the P-value is 0.3131, so it is not rejecting null hypothesis.

For Tv7Lv1 the P-value is 0.4924, so it is not rejecting null hypothesis.

FOR TV7SXS THE P-VALUE IS 0.00376, IT IS REJECTING NULL HYPOTHESIS.

The angles values which are differ in all three groups are with the statistical difference shown in boxplot below;

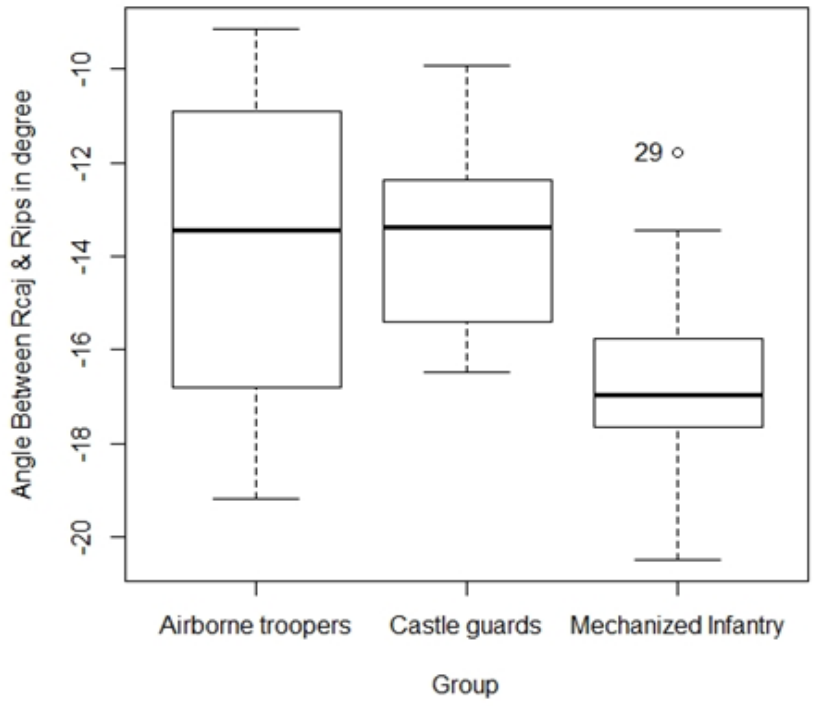

Figure 24 difference in mean value of angles between Rcaj &Rips between the groups

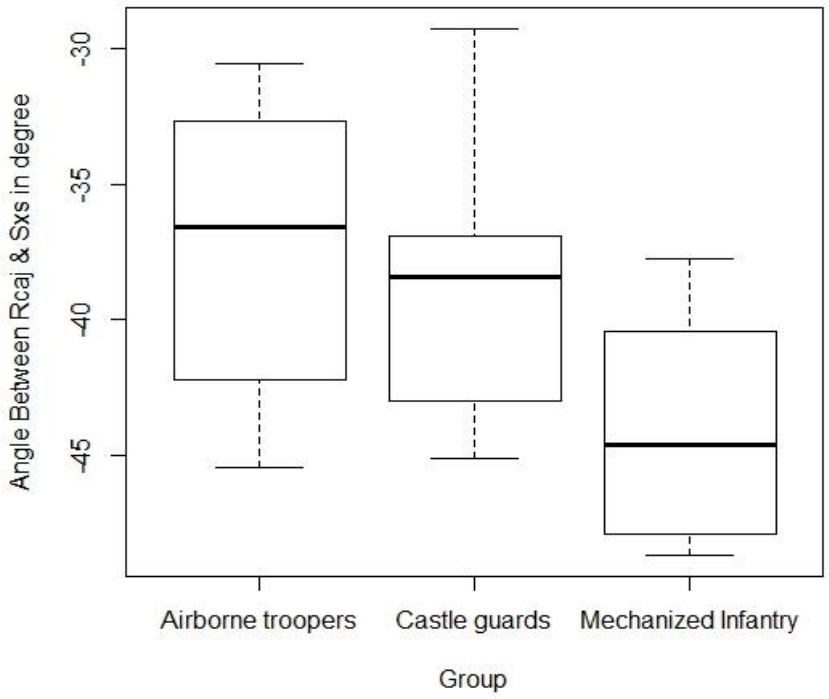

Figure 25 difference in mean value of angles between Rcaj &Sxs between the groups

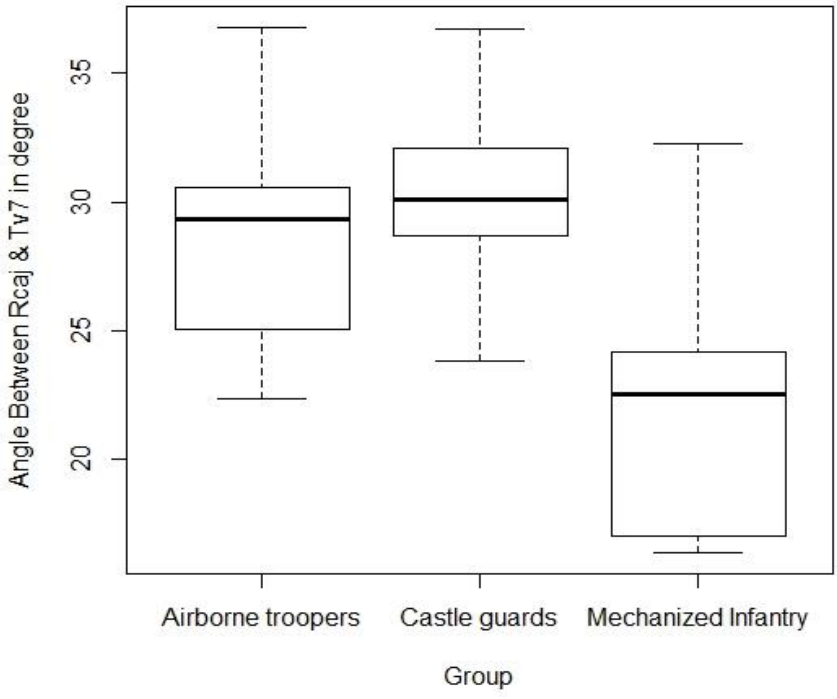

Figure 26 difference in mean value of angles between Rcaj &Tv7 between the groups

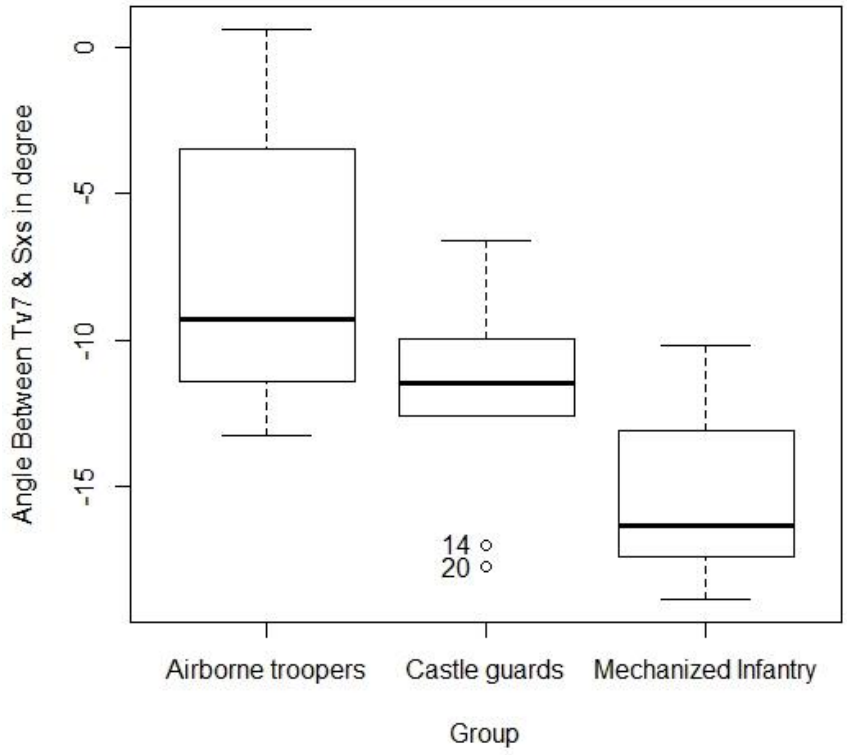

Figure 27 difference in mean value of angles between Tv7 & Sxs between the groups

Chapter 5 Discussion

As there is list of many systems and methods usable for the measurements of posture related studies there and on other hand the designed system which combines both version of Kinect camera as described above the use of both version1 and version2 are more effective and Nintendo Wii balance board which is easily available and low cost are the nicer combination for making the measurement system low cost compare to systems like vicon and Optitrack etc..

According to the study by Hejda J et al. the main advantage of this system is that it is hybrid portable system and it can easily combine in the transportable container which makes the system more effective for the specialized group like military professional that they can be able to perform the test on their choice of place so they don't need to come to any specific centre.

The test might be done in less amount of time because it does not take too much time like other systems to make it ready for the test and as the total price of the system is about 350$ which is way cheaper than systems like vicon which requires bunch of things such as motion capture software, plenty of vicon cameras and the big space for measurement[60]. The portable hybrid system uses less number of cameras and less software which makes the test more easy and comfortable for the person who is participating and also who run the test.

In the study nonparametric statistical test (Kruskal-Wallis) is used because the population is less in number as small groups of 10 participant in each group which makes the hypothesis easier to test. The Centre of Pressure and Centre of gravity results from the platforms show a higher range in the anterior-posterior direction, which is consistent with the assumption of side-by-side position of the legs. According to the Standard Deviation values of COG and COP are quite similar in all three groups because the statistics test are not rejecting the null hypothesis, where comparison with the angle between anatomical point the value of Rcaj & Rips are in negative which means that indicates downward slope in the direction of frontal plan of body, in the angle between Rcaj&Sxs airborne trooper's mean value is similar to the maximum value of mechanized infantry and it also indicates slope towards downwards. Other side the angle between Rcaj &Tv7 are in positive value in all three groups and mechanized infantry have better value than other two groups. In the angle between Tv7 & Sxs are in the minor negative way which shows minor downward tilt of spine. According to the research by Hejda J et al.The results in the tilt of the spine in the frontal plane presents that the quantization

level is in the level of measurement noise[49]. This is because of the limited depth map resolution of the Microsoft Kinect version2.

The mean values of above described angles in the mechanized infantry are quite not similar to other two groups it might be possible because of their duties which specifically include jumping with the parachute, there will be possibility to do more deep analysis of the group in future.

Where the other systems works on the force plate which evaluate only COG & COP, this portable hybrid system could be proven effective with the combine measurements of the angles between important posture anatomical areas like cervical vertebrae, lumber vertebrae and etc. System uses particular points from this areas which give correct detail from each angle between the points so it might be possible to say which state is better for the good posture of the participant.

In future research the sampling frequency will be improve and also possibility of increasing dynamic movement capture such as exercises like sit-ups and squats. The evaluation of data could be statistically differentiate by parametric methods when there will be more population of data.

Chapter 6 Conclusion

As the aim of the study was clear to design the portable and easily transportable system which measures the position of the spine, pelvis and centre of gravity of the body using Microsoft Kinect camera system and Nintendo Wii fit balance board as a stabilometric platform which makes the research cost less than other optical movement capture systems, in the study 30 military professionals from different specialized group were examined using the portable system as a tool in assessing posture and postural stability. After the statistical analysis From the P-value which is in the results shows that according to statistical test the standard deviation of the COG and COP in all three groups are nearby and there is no significant difference in the values as the test is not rejecting null hypothesis.

Then on other hand the mean values from different anatomical points through the angle between them shows the similar results in all three groups but there are some angle mean values which is rejecting null hypothesis so it might differs in that angles between anatomical points such as, **RcajRips, RcajSxs, RcajTv7, Tv7Sxs.** as the statistical difference are in the form of box plots above in results.

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Appendix

Table 2 Values of COGX and COGY Standard Deviation derived from airborne troopers

No.	COGX(SD in mm)	COGY(SD in mm)
Airborne trooper 1	1.373894213	3.026124019
Airborne trooper 2	0.957067747	3.459195032
Airborne trooper 3	1.073448977	2.872513955
Airborne trooper 4	1.057549335	3.030237607
Airborne trooper 5	1.045905645	3.324744537
Airborne trooper 6	0.679515459	3.319651582
Airborne trooper 7	1.143611002	6.413757986
Airborne trooper 8	0.877071783	3.466239156
Airborne trooper 9	1.237664508	1.896238055
Airborne trooper 10	1.353523406	2.311298403

Table 3 Values of COGX and COGY SD derived from castle guards

No.	COGX(SD in mm)	COGY(SD in mm)
Castle Guard 1	0.988636488	3.099281061
Castle Guard 2	1.990210211	4.632321097
Castle Guard 3	1.051327333	2.192222919
Castle Guard 4	1.096892309	3.491402905
Castle Guard 5	0.807261436	3.287206273
Castle Guard 6	2.068129784	4.839408473
Castle Guard 7	2.300517882	5.077247743
Castle Guard 8	1.706028481	2.848317772
Castle Guard 9	1.333699644	2.864753475
Castle Guard 10	1.130494597	1.793500822

Table 4 Values of COGX and COGY SD derived from mechanized infantry

No.	COGX(SD in mm)	COGY(SD in mm)
Mechanized Infantry 1	0.885599403	3.065344835
Mechanized Infantry 2	1.230405662	2.745284551
Mechanized Infantry 3	1.64819336	3.749811266
Mechanized Infantry 4	1.504611858	2.892243427
Mechanized Infantry 5	1.229050846	4.248430315
Mechanized Infantry 6	1.414616543	5.581155499
Mechanized Infantry 7	1.039606872	5.65235711
Mechanized Infantry 8	1.110791112	3.114589991
Mechanized Infantry 9	1.486024443	6.341774304
Mechanized Infantry 10	1.102635693	6.784499853

Table 5 SD Values of COP

Group	LCopX	LCopY	RCopX	RCopY
Airborne trooper 1	0.372677996	2.893369955	0.539267399	3.350669368
Airborne trooper 2	0.779286722	2.954971281	0.975193187	4.48835479
Airborne trooper 3	0.544537012	3.74827859	0.378254623	2.332781913
Airborne trooper 4	0.968835921	4.324021555	0.964753156	2.074740477
Airborne trooper 5	0.535125262	1.918858035	1.528420321	5.071599459
Airborne trooper 6	0.393117616	2.882221331	0.415852468	3.900551136
Airborne trooper 7	1.410989236	6.863497545	0.980544572	5.982329191
Airborne trooper 8	0.802904151	4.473511267	0.517595732	3.020695257
Airborne trooper 9	0.529038427	2.348248453	0.344061044	2.127309048
Airborne trooper 10	0.534421817	2.879345123	0.493698919	1.937476018
Castle Guard 1	1.213009996	3.418830509	0.772046262	3.121520546
Castle Guard 2	0.66283567	4.476238212	1.008701026	5.107038473
Castle Guard 3	0.441688394	2.664217125	0.415900196	2.274455394
Castle Guard 4	0.663245235	3.310995462	0.569391619	3.887406223
Castle Guard 5	0.582736233	2.661292172	0.594071261	4.174736156
Castle Guard 6	1.802559598	5.604823389	1.623005154	4.924737577
Castle Guard 7	0.861876992	7.155305822	1.461104933	4.858783466
Castle Guard 8	0.477848942	3.285227098	0.463379295	2.906625026
Castle Guard 9	1.086523345	5.473447061	0.254267551	3.122418149
Castle Guard 10	0.621137309	1.315027383	0.565216776	2.579246394
Mechanized Infantry 1	1.0012333	2.976964903	0.868456315	3.271783309
Mechanized Infantry 2	0.644532699	3.250757492	0.568012758	2.370196545
Mechanized Infantry 3	1.223758502	5.228174806	1.01117024	3.60648008
Mechanized Infantry 4	0.94253708	3.214318961	0.996172751	2.892349794
Mechanized Infantry 5	1.569122278	5.192992307	1.295593544	7.252408815
Mechanized Infantry 6	1.306932475	7.166642852	0.677666422	4.504909259

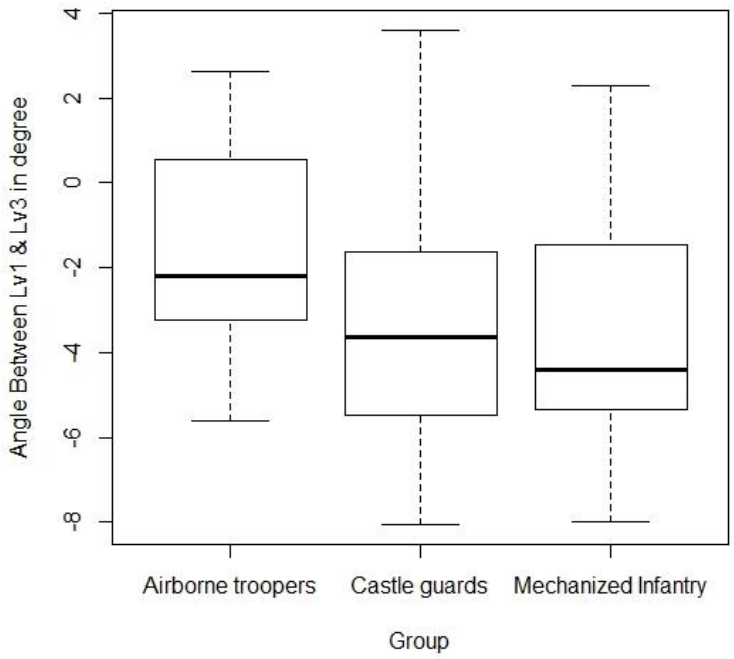
Mechanized Infantry 7	2.05923386	7.052801124	1.211300217	4.778703085
Mechanized Infantry 8	0.96093811	2.350730225	1.933870735	4.600460819
Mechanized Infantry 9	2.817907284	6.60593492	2.836060782	6.239682992
Mechanized Infantry 10	1.06050759	6.565125043	1.262715357	7.197019127

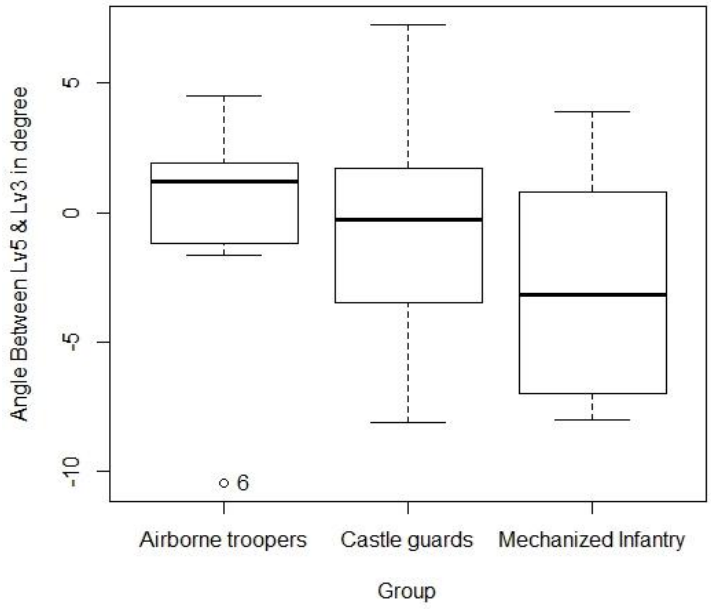
Table 6 Mean Values from different Angles (Group1-Airborne troopers, 2-Castle guards, 3-mechanized infantry)

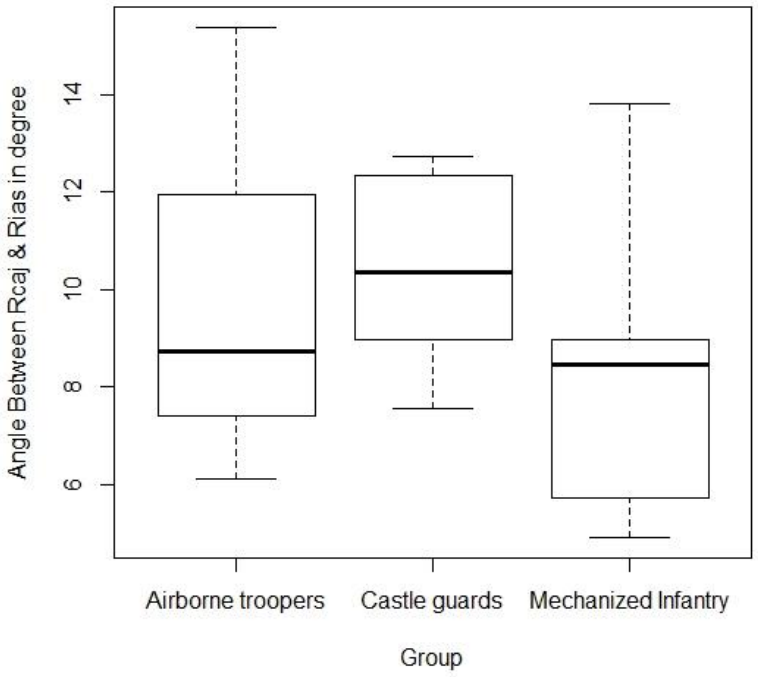
Cv7Tv2	Tv2Tv7	Tv7Lv1	Lv1Lv3	Lv3Lv5	RcajSxs	RcajTv7	Tv7Sxs	RcajRips	RcajRias	RipsRias	group
-0.02963	0.529012	-4.25617	-5.61852	-1.17222	-31.6759	34.87716	0.609259	-9.35123	13.65247	-13.9969	1
5.703268	-2.24052	-5.53725	-1.70131	2.904575	-42.5954	22.33595	-10.9379	-19.1961	6.81634	-12.7366	1
-4.6788	-0.19783	-0.39457	-0.68804	1.213587	-36.6837	30.55489	-7.6837	-14.6076	8.326087	-21.3853	1
5.184106	-1.08609	-6.51325	0.605298	-1.62781	-32.704	29.82318	-11.4358	-10.9007	8.82053	-24.655	1
5.185393	1.455056	-5.01685	-3.22247	-0.92865	-33.0674	29.44213	-13.2635	-11.1607	11.94045	-9.92921	1
2.758659	0.194972	-0.44916	-2.94302	-10.4279	-36.5123	29.27095	-3.45196	-14.5458	10.40447	-8.50447	1
12.32697	2.071348	-4.7	-4.43427	1.925843	-30.5764	36.77416	-4.98708	-9.14944	15.37978	-3.07191	1
-4.41453	4.106145	-3.9676	-2.69497	1.150279	-36.6631	25.2067	-3.3257	-12.3436	8.643575	-12.6235	1
19.56176	-0.23059	-1.01941	2.617647	1.344118	-45.4459	22.35353	-12.6971	-16.7888	7.4	-21.93	1
7.693296	-0.5676	-4.00223	0.555307	4.523464	-42.2346	25.04693	-10.9542	-18.3793	6.113966	-13.4989	1
0.868984	2.249198	-6.48984	-5.48877	7.238503	-38.3337	28.67005	-10.384	-16.4882	8.641711	-15.0364	2

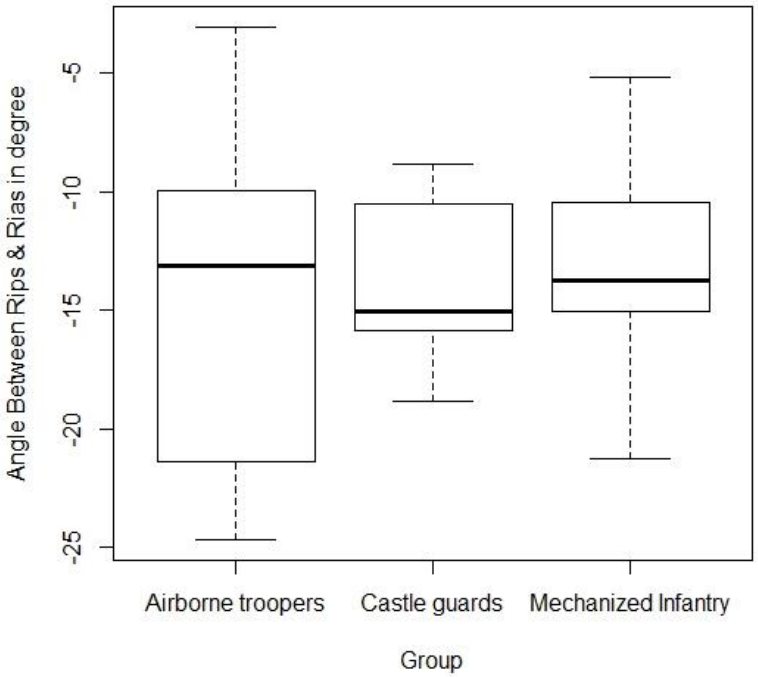
8.591327	5.678571	-3.95867	-5.46888	0.739286	-37.4622	36.72959	-11.5056	-9.92755	12.73622	-10.5469	2
4.306989	3.247849	-6.13925	-4.16183	0.816667	-43.3995	31.02473	-12.0823	-13.4715	12.33602	-10.2882	2
10.88919	1.177838	-0.78919	-2.98541	1.708108	-42.9897	25.34973	-17.0265	-12.3778	8.964324	-15.8757	2
13.10699	4.932258	-0.93602	-8.04086	-8.08763	-38.4737	33.25269	-11.4419	-15.8059	12.68065	-18.8339	2
1.506	2.5075	-3.5915	3.5875	2.6875	-38.496	28.9765	-9.964	-12.826	10.28	-15.472	2
1.303191	1.070745	-1.16277	-4.31702	-2.46702	-29.2787	31.31543	-7.05426	-10.8824	10.45851	-18.7782	2
-2.11422	-0.26078	1	-0.92598	-5.02843	-45.1049	29.21863	-12.602	-15.3975	7.563235	-15.0348	2
0.679703	-0.18366	-3.37327	-1.63911	-1.26782	-36.9163	32.12129	-6.59505	-13.7257	11.0896	-8.86782	2
-0.35024	-0.9756	-1.81627	-3.10813	-3.49043	-36.711	23.80813	-17.7713	-13.2646	9.590431	-14.4789	2
5.179186	1.256109	-3.00136	2.065611	0.949321	-37.7796	17.05385	-18.8475	-15.7751	7.981448	-10.4819	3
-2.57357	-1.23877	-1.02335	2.281498	3.885903	-41.3101	16.57709	-15.6163	-17.0872	5.723789	-14.3159	3
8.627619	-0.40571	-3.82619	-4.53619	-4.7781	-45.2943	19.81238	-17.489	-20.4748	4.925714	-12.7114	3
-0.76616	1.650505	-2.23737	-6.01212	-1.91465	-47.9455	24.19798	-16.0495	-17.6616	8.929798	-13.1525	3
7.120792	5.250495	-2.72772	-4.43713	0.780693	-48.6812	24.16337	-16.7995	-17.2342	6.234158	-21.2495	3
2.167982	-2.13377	-2.27368	-1.45526	-8.0193	-45.0544	21.9307	-13.0781	-16.125	8.983333	-19.5	3
-4.68103	2.237436	-2.57436	-3.99333	-1.77128	-37.7462	26.48154	-10.2159	-13.4538	11.60769	-5.78513	3
8.682292	-1.57188	-2.95156	-5.33698	-4.47656	-47.9625	23.18333	-16.6089	-17.7656	8.98125	-14.325	3
6.961497	4.565241	-5.75668	-7.97059	-7.58503	-40.4342	32.27219	-11.5775	-11.7786	13.81497	-5.20321	3
6.175661	3.290476	-1.74974	-4.3746	-6.97884	-44.1815	16.40476	-17.4069	-16.8587	5.631217	-15.0524	3

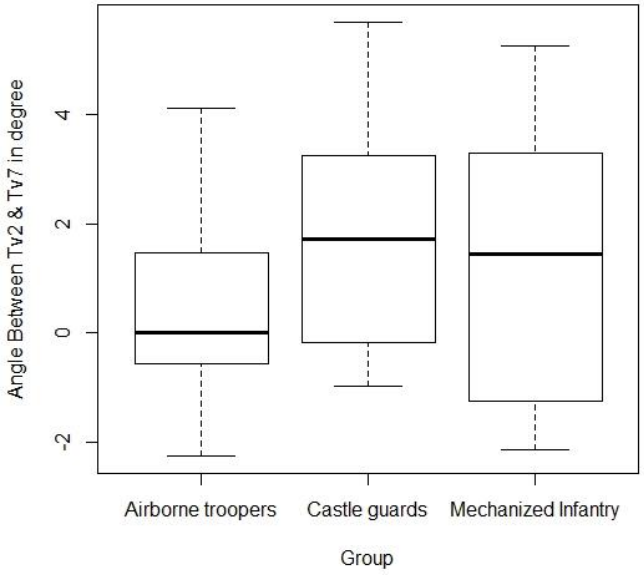
Box plots from angles between anatomical points which are not rejecting the null hypothesis are as shown below;

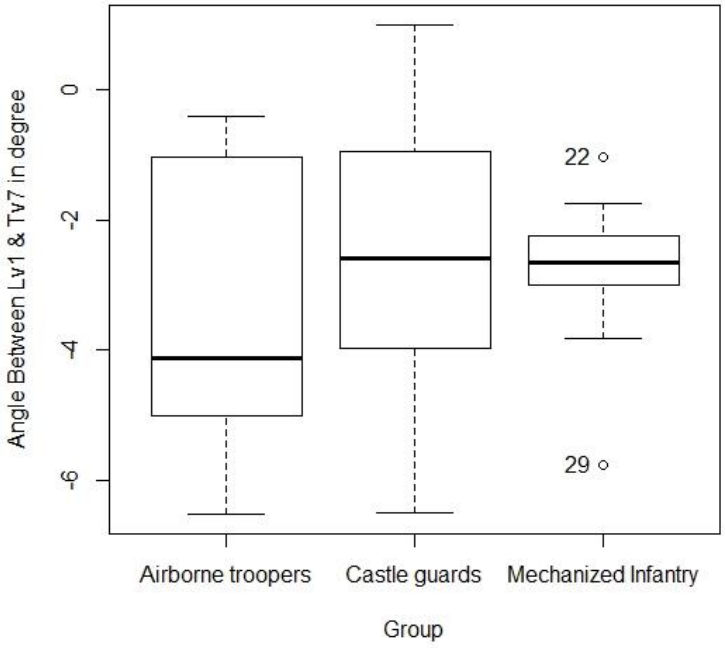





Angle Between Rcaj & Rias in degree
6
8
10
12
14
Airborne troopers
Castle guards
Mechanized Infantry
Group


Angle Between Rips & Rias in degree
-25
-20
-15
-10
-5
Airborne troopers
Castle guards
Mechanized Infantry
Group


Angle Between Tv2 & Tv7 in degree
-2
0
2
4
Airborne troopers
Castle guards
Mechanized Infantry
Group


Angle Between Lv1 & Tv7 in degree
-6
-4
-2
0
22
29
Airborne troopers
Castle guards
Mechanized Infantry
Group