A BIOMECHANICAL POSTURE ANALYSIS BY USING ERGONOMIC AND KINEMATIC APPROACH DURING WATER LIFTING IN THE RURAL AREA OF JHARGRAM, WEST BENGAL

A thesis submitted towards the partial fulfilment of the requirements for the degree of ***Master of Engineering in Biomedical Engineering*** *Course affiliated to*

Faculty of Engineering and Technology,
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CERTIFICATE OF RECOMMENDATION

We hereby recommend that the thesis entitled "**A biomechanical posture analysis by using ergonomic and kinematic approach during water lifting in the rural area of Jhargram, West Bengal**" carried out under supervision of Prof. (Dr.) Abhijit Chanda may be accepted in partial fulfilment of the requirement for awarding the Degree of Master in Biomedical Engineering of Jadavpur University. The project, in our opinion, is worthy of its acceptance.

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The forgoing thesis is hereby approved as a creditable study of an engineering subject carried out and presented in a manner satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein but approves the thesis only for the purpose for which it is submitted.

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains a literature survey and original research work by the undersigned candidate, as part of her Master of Engineering in Biomedical Engineering studies during academic session 2020-2022.

All information in this document has been obtained and presented under academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred all material and results that are not original to this work.

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ABSTRACT

Every individual works and their work situation make social status, health status, development and self-efficient. Good postures while working is the wonderful way to have productive and healthy work-life, therefore no more using heavy loads and harmful postures. In today’s life, with having competitive life, work containing repetitive movements with a certain duration are very well monitored. And about to reduce the number of risks as much as possible. Since the risk is known. But still sometimes smaller loads can affect our body and put it at risk. Because of this project it was found if any harmful postures are there or not. If it is there, then it may turn out to be a huge risk of injury.

The purpose of this project was to investigate the biomechanical concepts and ergonomics concepts in women’s body while pulling a load (fetching water) a bucket of water out of the well by using rope in a rural area. This work is their daily life work. This work was done by identifying the present ergonomic state in the village using the ergonomic evaluation method. This study has approaches using ergonomics theories and some research questions are need to verify. This study was also done using human motion analysis. Analysing the joint using trajectories to know that how much time a joint is staying in static position and if joint is moving then what will be their speed. For ergonomic method, we have used RULA and REBA. And for analysing method, KINOVEA software were used to evaluate joints' angular and linear motion. The angular displacement will show the angles between the joints during work. The risk assessment is known from the RULA, REBA scores and it will reveal the exposure level of risk by score. Other than ergonomics and mechanical processes, to know the health information and risk information a personal information record is needed and a standard questionnaire for musculoskeletal disorder has to go through. And some interviews were taken to conclusion of musculoskeletal disorders.

Having an ergonomic approach and a mechanical approach can lead us to understand biomechanical understanding. So, biomechanical work has to be done. It finally cleared that the loading understanding and the relation that helps to see musculoskeletal disorder while working.

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1 INTRODUCTION

Getting a bucket of water from well by using hands is a part of life of some Indian villagers. Unknowingly, people of some villages put their life to an effort and a risk for their life every day. There were days when villagers had to pull a backet of water without pulley, directly using rope. Then, they used to pull it using pulley and still doing and the height of the well was so low. Nowadays, from the help of government, the well height becomes higher and tied up by concrete. And some of the villagers have tube well, submersal etc., but they are 10% people of the whole population. The research that has done in two villages named Tiakati and Lalbona, Jhargram, West Bengal. Here, man and woman both had to do this performance for their daily life work i.e., bath, drinking, house cleaning, and personal staff. They are doing it from the age of 8. At first, they started it by curious. Then as they become responsible at the age of 12 or lower than that, they started to doing it for themselves. But after the marriage which is basically undergone by the age of 14 to 16, all the house chores, have to done by the woman. Even they have to work in their pregnancies. They used to pull out water from the well in that condition. India is still a developing country but still in some village there are inequities. So, in the area where water is considered life but still cannot access in a healthy way, can be led to some serious issues. Health related issues are very much inconsiderate in villages. One survey said one out of ten percent of global issues are related health. Improving access to safe water can lead to have a improve in postures. If improvement of accessing safe water cannot be prioritized, a larger problem on human body can be found. As example, it is seen that people who collect water can have some health-related issues as consequence [6].

Some of them carry water container filled with waters on the head. But some of them transported the water on the cycle. But fetching water from well can be affected by body potential. Carrying or lifting water regularly minimum 8 times a day can led to musculoskeletal disorders (MSDs) because it can lead to stress on body [6,9,10]. External load within the capacity may help to strengthening body parts by adapting it. But if the external load goes beyond the human capacity, then it might lead to some serious injuries by having fatigue failure [11] or can lead to changing bone and soft tissues.

Assumptions says that water carrying and lifting is related to health problems and lead to MSDs such as joint pain, back pain [8,13,14]. These kinds of assumptions are the evidence that working throughout the body while handling heavy materials, lifting, putting down, continue repetitive movement of body, bending are the factors of having low back pain [11,15] and other musculoskeletal disorders [16,17]. For the professional survey, it has showed that mostly carrying heavy loads on the head led to spinal fracture or dislocation [18] or it can lead to changes in cervical spine [12,17,19,20].

Few studies showed that most of the time water carried by women and children used inappropriate methodology. And very few use the appropriate methodology. It is shown that mostly impact on body happens for men. For woman, survey methods or any other methods are done less so, the data for women are low. But still has conclusion on those women and children that they have low tolerance for injuries than men [30,36]. But in rural area, because of literacy, poverty, poor health conditions, problems in women body are seen as inconsiderate [37-42].

It is not still cleared whether regularly working condition & working environment are the reason for the change in the spine and other joints for their domestic water collection. It is also not knowing that whether their quality of life has impact on health.

But water lifting can be a very healthy exercise and beneficial for health for some people. So, in research the study should be studied broadly [7]. From the previous studies it can be said that the methodology is biased for determining the outcome.

1.1 Biomechanics

Studying mechanics principles in the human body is said to be biomechanics. It also saying that, studying external- internal forces in human body because of which body moves also called biomechanics. Whether small plants or largest animals, all shows several forces and stimuli. But in human body biomechanics is referred when the study is done under muscular- skeletal system. In biomechanics, scientist and researchers try to find out a problem and solve them with physics and mathematics and understand the capabilities and limits of the human body. Now, in the one of the largest industry "Healthcare" system is trying to work on the other hand with biomechanics and biology throughout the hospital and university.

1.1.1 Modern Trends of Biomechanics

The entry of biomechanics in the field of research is making an identified relation toward the science such as neural physiology and exercise. The neuromuscular system includes the muscles and nerves. Every movement is done by brain and muscles and their connection.

From a diagnostic approach to evaluation method, biomechanics is used as unique study in order to analysis and bring out better performance as output. Through the help of anatomical point of view and physics, biomechanics helps neural system to charge in the new era. In this modern era, using biomechanics knowledge, one can perform better in the field of sport and healthcare system. It can bring out a new skill on the other level. The major goal of biomechanics is to enhance the performance in the better way.

1.2 Plane and Axis of Human Body

1.2.1. Plane

It is the imaginary surface along which the movement of human body takes place. There are 3 types of planes considerate here –

- *Sagittal Plane (movement in a vertical plane):* It is the vertical plane. In this plane, the human body gets divided in right and left sides. It is the combination of anterior and posterior because in this plane we can see some part of the anterior and posterior view of a human body. Example of movement in this plane can be such as, jumping, walking, nodding etc.

- *Frontal Plane (movement in the coronal plane):* It is the anterior portion. Therefore, it can be said that frontal plane divided a human body in front and back. Example of lowering and raising hand, cartwheel can be included.

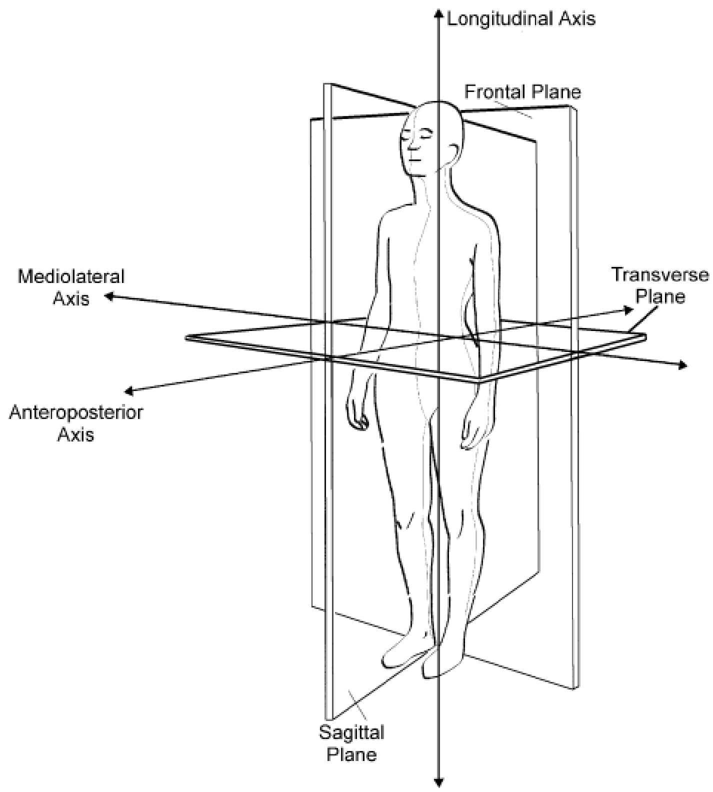

Figure 1-1 Plane and axis according to human anatomy

- *Transverse Plane (movement in a horizontal plane):* In this plane, human body gets divided in two halves (upper and lower) horizontally and the movements that occurs are relatively parallel to ground. In this plane, movements are not affected by gravity. In this plane rotation types movements are generally done. Example, hip rotation, head rotation etc.

1.2.1 Axis

It is defined as the imaginary line about which the movement takes place. There are also three types of axis around which body or body parts rotate.

- *Frontal Axis (mediolateral axis):* It is a horizontal line. This axis lies from left to right through the body center. Movements in this axis lie in the sagittal plane. For example, when a person pulls or push, rotating hand exercise.

- *Sagittal Axis:* It is the transverse axis from front to back of the human body and throughout the center of the human body. That’s why it is known also as anteroposterior axis. The movement in this plane projects on the frontal plane. For example, when a gymnast performs cartwheel.

- *Vertical Axis:* It is the vertical line lie parallel to gravity or top to bottom through the center of gravity of the human body. The movement of this axis projects on the horizontal plane. For example, when a dancer spins around the vertical axis.

1.3 **Motion**

In the biomechanics, a motion is said to be a phenomenon where an object changes its position with respect to surrounding with time includes motion without force producing it.

Types of motion in a body

Generally, it is categorized into three parts –

Rotary Motion: In this case, when an object moves along a circular path with fixed axis. Each and every point on the object moves to same distance with same angle.

Translatory Motion: When an object moves along a straight line, it is called rectilinear motion. When all points of the body, moves through the same distance ant same time is called translatory motion.

Curvilinear Motion: in this case both rotary and translatory motions are combined. It is the typical form of human body joint.

1.3.1 Posture

Posture is said to be the position of the human body to hold limbs whether in standing, sitting, squatting, working, cooking, dancing etc. To have a good posture one needs to work on her/himself. A posture is said to be good when it have less stress on back during different times of working i.e.; kneeling, bending, lifting. The muscles and other parts change their position in order to perform a work.

There are two types of posture –

Inactive Posture: in this type of posture, mainly muscles are in relaxed mode or resting mode such as sleeping or resting. This took the least energy and action.

Active Posture: In this type of posture, muscles and energy is needed. It is two types –

- Static Posture: Here, the body is in use keeping the body static like standing, sitting, kneeling, etc. In this posture, the body parts are aligned for the time until the work is finished. It needs energy.

- Dynamic Posture: In this posture, the body parts are continuously moves to perform a task.

1.3.2 Good Posture

It is called as attitude of the body and body parts to keep up balance and stability with low effort and low strain in supportive and non-supportive spaces.

To gain and maintain good posture one has to be aware of the essence of muscle and joints working in optimal condition. One's back is supposed to be called healthy when it has three natural curves and these are –

- Cervical curve which is a slight forward curve in the neck.
- Thoracic curve which is slightly backward curve on the upper back.
- Lumber curve which is slightly forwarded in the lower back.

  Good posture is all about keeping balancing these three curves through alignment. For good posture, flexible and strong muscles are needed. If abdominal muscle, back muscles, hip muscles, and leg muscles are weak, then it is very much hard to support one's back's natural curve. As we walk, our leg muscles and hip muscles help to support our spine and its position. As we work or do any task during bending and kneeling, our abdominal, hip, leg muscles undergo stress and try to support the spine and helps not to change its position. The curve of spine changes as we grow older and the task influence the posture and therefore, it becomes difficult to maintain a certain correct posture. Some of the changes are –

  - The disc in the spine started to become weak and cannot function properly to given external forces such as body weight and gravity as the muscle around the waist becomes inflexible.
  - Because the compressive forces act on the spine made it collapse and cause injury which can be seen in patients with osteoporosis and people with forwarding bending.

- Lifestyle becomes inactive. Sitting prolongation of time make much shortening the muscle which can bring out the poor posture, therefore it weakened other muscles which can depress the body.

Although the changing and aging, one can control and maintain the good posture and improve the bad posture.

❖ **Importance of Good Posture**

Maintain good posture daily can help a person to get into less injury. Some importance are –

- Good posture conveys a good impression of an individual of their wellness.
- Good posture shows alertness of an individual's personality. It has a relation between good posture and good health.
- Good posture brings out alertness which is done by habit and discipline to lead a healthy way.
- Good posture makes higher efficient movement with minimum effort.
- Good posture maintainer performs very efficiently and effectively and improves their prospect.

1.3.3 Bad Posture or Poor Posture

Bad posture is always made by habit more than any high incident. It can be due to misuse of muscles, prolong use of muscles or using muscles beyond capacity. Postural dysfunction is said to be when one spine is making an unnatural position, where the curves are features to be in a stressful position with joints and muscles. The prolonged period of positioning make pressure on the curve tissue. The painful condition that work on the poor posture are so common that people mostly have some knowledges.

Lower back pain is the most complaint in the healthcare industry but researcher has found out that with lower back pain, neck, shoulder and arm pain also has increased as postural problems.

Foot and knee dysfunction has also become more and more common due to fitness and running program of individual. Body aching including upper-lower back, neck, shoulder and arm pain. Lower limb included ankle or knee, leg and hip pain. Muscle fatigue and tension in the muscle can cause pain the upper back, neck, shoulder area.

- **Cause of Bad Posture**

There are huge number of causes that results bad and poor posture. Some of them are –

Injury: When an injury occurs in muscles or ligament or bone, it will weaken the support and will make an imbalance.

Disease: It affects any posture very quickly. It will make muscles or bones to lose their strength and mobility in any joint. Example, rickets causes bone to lose its strength. Infection in bone can cause its joint to lose its mobility and strength.

Habit: Whether good or bad posture, they occurs in the same way of habit of walking, sitting, etc. Wrong habits can lead to have bad posture through some occupational environment.

Weakness: A good posture need good energy. So, until and unless maintain a posture without energy, it can lose strength and endurance.

Mental Attitude: A person's posture changes as his/her mental ability changes. A person with depression can lead to have bad posture.

Heredity: Heredity problem like kyphosis and other genetical problem can cause to have an individual to have bad posture.

Improper Clothing: Type of dress matters a lot to maintain a posture. If the dress is too tight, shoe is tight etc. can lead to adapt bad posture.

Improper Diet: It can lead to have an improper deficiency of minerals and vitamins which turns again a result of having bad posture.

Chronic Fatigue: Lack of rest and continuous work day by day leads to develop fatigue which turns into chronic fatigue.

Overload on work: People who overloaded with work continuously can causes having bad posture.

Imitation of postures: There's a tendency of children to imitate their favorite characters either it can be teachers, heroes of tv shows, models, star and therefore it can lead to have a bad posture.

Age: As we get older and older, it becomes our habit to bend lower and lower most of the time because of inflexibility. So, we avoid doing exercise and movements thinking of putting us in discomfort. So, we lose muscle strength which turns us into bad posture.

Weight of body: Extra weight on the waist area can pull the pelvis forward and make an unalignment of the spine and add stress to the lower back. Example, woman who has a large breast experience back pain.

Fashion: Too tight clothing, heavy bags, and walking with high heels can cause back pain. High heels can push the center of mass of one's forward, making the hip and spine unalignment and causing additional strain on the back, knee, and ankle.

Unhygienic Condition: For example, improper sitting in the classroom, insufficient furniture, etc. in our country, can causes postural deviation.

Improper routine of lifestyle: Sitting prolong period of time in school from childhood can cause spine to have improper maintenance and lead to fatigue in spinal area that becomes habit to having bad posture.

Lack of Exercise: Exercise helps a person to increase muscle strength and flexibility. So, lack of exercise can cause one to have lack of flexibility, improper digestion, losing physical ability.

Lack of Awareness: People with awareness of having good posture can maintain their posture in a proper way. But lack of awareness may make people to have faulty posture.
Obesity: Obesity or overweight puts extra stress on the musculoskeletal system resulting in postural deviation is happened and turns out to be bad posture.

Poverty: Lack of basic needs and goods due to poverty is essential factor of having bad posture.

Occupation: Some occupation needs sitting, or standing in an improper way for a prolong period of time which can cause to have bad posture.

❖ **Symptoms of bad posture**

Most of the time it has been seen that in the static posture 50% of the muscles are in the contracted position which means that the forces on the body are higher than moving.

The problem occurs when there are imbalances, pressure in the spinal disc area which decrease the blood flow in the spine. The symptoms of bad posture are –

- Pain in the neck or shoulder area.
- Tension headaches.
- Numbness or heavy pain in the arm.
- Constantly generated pain in the lower back.
- Overall body aches.
- Repetitive strain due to working on a task prolong period of time.

1.4 Mechanical Analysis of Movement

❖ Range of Motion:

Range of motion is the range of how much a human body can stretch or compress a body part in the joint. It is measured while flexion, extension, abduction, adduction and rotation in a particular joint. The general range of motion of human body joint is given here –

- **Range of motion of Upper Limb**

➢ **Shoulder joint**

- Flexion: 0-180˚
- Extension: 0-60˚
- Abduction: 0-180˚
- Adduction: 180-0˚
- Medial Rotation: 0-70˚
- Lateral rotation: 0-90˚

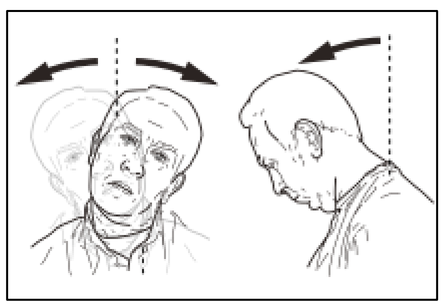

Figure 1-2 Neck extension-flexion

- **Elbow joint**
- Flexion: 0-135˚
- Extension: 135˚-0
- **Forearm**
- Supination: 0-80˚
- Pronation: 0-80˚
- **Wrist**
- Flexion: 0-80˚
- Extension: 0-70˚
- Radial deviation: 0-20˚
- Ulnar deviation: 0-30˚

Range of motion of Lower Limb

- **Hip joint**
- Flexion: 0-120 ˚
- Extension: 0-30 ˚
- Abduction: 0-45 ˚
- Adduction: 0-30 ˚
- Medial rotation: 0-45 ˚
- Lateral rotation: 0-45 ˚
- **Knee Joint**
- Flexion: normal: 0-145 ˚
- Extension: normal:145 ˚ -0
- **Ankle Joint**
- Dorsi flexion: normal: 0-20 ˚
- Plantar flexion: normal: 0-50 ˚
- Inversion: normal: 0-35 ˚
- Eversion: normal: 0-15 ˚

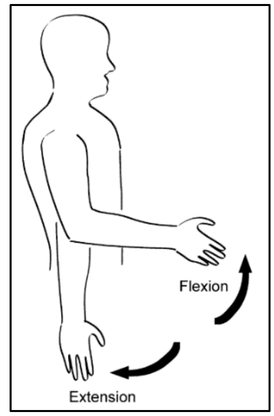

Figure 1-3 Extension and flexion of hand

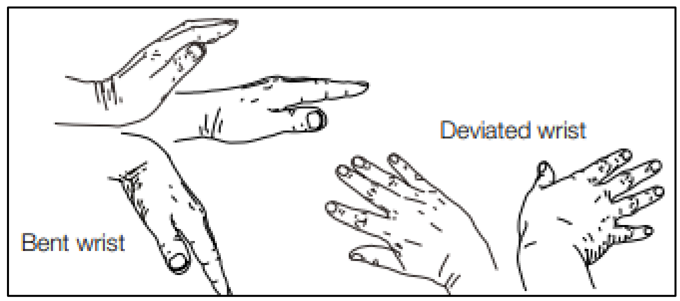

Figure 1-4 Wrist bend and wrist deviation

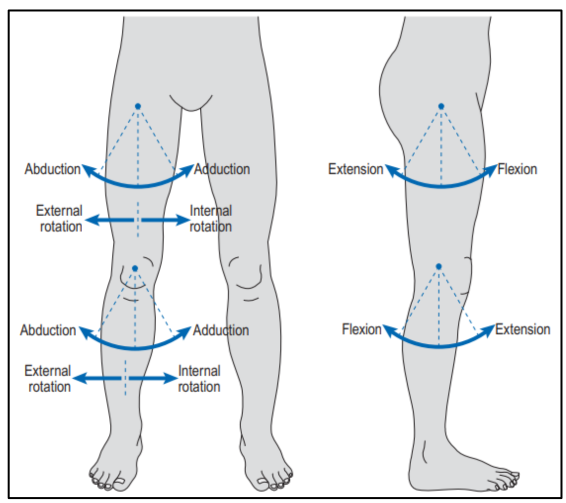

Figure 1-5 Extension, Flexion, abduction and adduction of leg

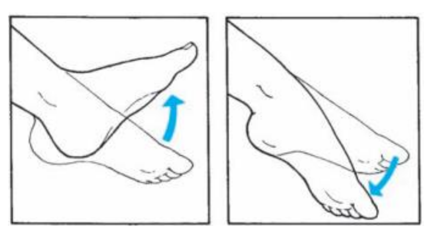
Figure 1-6 dorsi flexion and plantar flexion of feet

2 AIMS & OBJECTIVES

Aims and Objectives

- To find the RULA score of each participant and evaluate the posture.
- To find the REBA score of each participant and analyze the posture.
- To find the ART score of each participant and evaluate the posture.
- To find the musculoskeletal disorder risk information.
- To find the movement pattern in a simple way i.e., stick human model.
- To find the joint linear displacement and velocity along x direction and y direction.
- To find the speed of each joint.
- To find the total distance travelled by joints of upper and lower limb.
- To find the inner angle between each joint.
- To find the force generated in hand.
- To find the relationship of co-efficient of friction of rope and pulley.
- Relationship of load ratio and contact angle.
- Relationship of logarithmic force ratio with contact angle.
- Relation between carrying load and angles of joint.
- Relation between carrying load and maximum displacement of the joint.

3 LITERATURE REVIEW

Review of literature has its own purpose. Basically, its first purpose is to carrying out and evaluate the previous works that already had been done before and contributed to research phenomena. The review begins with an analysis of human body postures, human body movements and then focus on the risk assessment and injuries. This review also included some theoretical knowledge and human movements, postures.

Literatures were searched in the following database such as – PubMed, ScienceDirect, ResearchGate, Academia, NCBI. We used online searching engine Google and Google Scholar to go through the above websites to identify source through internet. We searched paper from 2007 to 2021, September.

The aim is to study to find out work related discomfort, awkward postures, risk assessment by undergoing a no. of methods. So, a no. of methods is identified and they are categorized in three different category that are used by previous researcher conventionally for reviews [1,2] are –

- Self-reports.
- Observational methods.
- Direct measurements.

Self-reports are done by collecting data through interviews and questionnaires at the workplace where physically works are done to understand physical and psychological factors. Data collections has become a work that comes under written records, collecting previous records with or without any external conditions, and then self-evaluations is done after analysis is done in the recorded video [17] or we can use web-based questions and standard Nordic questionnaires [18].

Methods of self-reports are very easy to use at the workplace. It can use when larges samples are provided, large conditions of work are given. It is not expensive. But the disadvantage is it is time consuming and unreliable and imprecise. Because at the same workplace, comparison probability within the workers can be low. Another reason is, collecting data is difficult due to depend upon worker literacy, comprehension and understanding questions [27]. So, the level of exposure is doubtful [20]. So, other methods can be used for identifying the problems in details.

Simpler observational technique: a no. of simpler methods are developed at the workplace exposure. In these techniques, the exposure has to done with record and observe. The exposure factors depend on different techniques. Some permits only postural assessment and majority of them assess physical exposure factor [35,36] to gather subjective data from workers. These methods are inexpensive and practically usable in a huge rage of workplace. It goes under intra and inter observer variability and suited for repeatable work and static work [1].

The exposure factors are determined by a combination score while analysis [31,32,35,36,38,43] having a certain task. The data upon which scoring system is based is limited. As it is depended upon different factors such as weight, joint angle, duration, pattern etc. The scoring system is hypothesis.

Direct method: This can be done by sensors that are attached to the subjects for measurement. Some light weighted device developed for application for measurement at finger and wrist angles and forearm rotation [58] by computerized data analysis. Systems are used for simultaneous recording at multiple wrist, hand and finger movements together.

With appropriate software it is very easy to indicate some data and record through the sensors to the software and study the assessment of body postures and movements by monitoring [59,60]. As example- EMG is another method which is recorded synchronously and analyzed by computer [61,64].

Many investigations have showed use of new device to measures angular positions of an extremity of human body. The lower limb is the part of human body that need measurement and evaluation due to disabilities [5-8]. The disadvantage in here, it is difficult to obtains angular measures at the leg without reference system.

In [9], the measurement of movement was done by using Wii Remote with IR sensors. In this movement, IR LEDS and glove, here, the system always be made XY origin, the movement is registered by reflection of IR LEDS and then it will be capture by IR camera of the Wii Remote.

In the similar investigation, accelerometer is used to measure the movements of wrist [10]. Later, for improvements of quality of measurement of therapeutic robots [11] Celik proposed haptic joystick. The study then was compared with measurement of clinic and movements, then analyzed [12-16]. The systems needed hardware, electrical law control, law to implement [17]. Finally, then a training system was developed for real time measurement of lower limbs by Shin [18].

The previous researches were done using some observational methods having term as given below- observation, lifting, workload, manual material handling, risk assessment, ergonomics. And there is also musculoskeletal systems term i.e., back, neck, hip, extremities. Some strategies are allowed to identify risk assessment since performance strategies are known, so some additional search was done to have some identical methods or problems with having some reference.

Bryman and Bell (2015) state that increasing credibility in literature only can be done for whom is knowledgeable in that area. There has to be a purpose of exploring the literature that are existed i.e., gaining knowledge and can answer following questions-

- What are the things that already known?
- Are there any concepts and ideas about the relevant area?
- What kind of methods and procedures that are already applied to this area?
- Were there any controversies in the relevant area?
- What are the findings that we’re looking for?
- Is there anything that still undone?

Research on water fetching, lifting, postures, WMSDs, risk assessments: While studying MSDs, it is very much dependable on loads, repetitive movements, working awkward postures, couple, pain (Kulkarni & Devalkar 2017).

Ergonomics is a postural assessment tool that used for studying posture and then scoring posture for understanding risk assessment. RULA & REBA are very helpful ergonomic tools that reads and score postures assessment which is described in (McAtamney and Corlett, 1993) and (Hignett and McAtamney, 2000).

Ergonomics tool is very easy to find out postural score without any machine and instrument. Ergonomics score is something upon which we can predict the risk. From RULA & REBA method, it is useful to knowing the pain in the body and fatigue as described in Bhandare et al. (2013).

There's another tool named OWAS that is useful for reading posture of construction industry workers. OWAS has different objective postural risk according to risk level and can be given correct steps to reduce risk level and growing improvements that described in (Lee & Han, 2013).

There are some observational methods given in the Table 3-1 with its own strength, limitations and mode of recordings including target exposures.

Table 3-1 Some observational methods as per previous records

Methods		Recording mode	Observation Strategy
General methods	Ovako working posture assessment	Pen-paper, computerized	Time sampling
	Posture targeting	Pen-paper	No rules
	3. Ergonomics Analysis	Video, computerized	No rules
	Posture, activity, tool and handling	Pen-paper, video, computerized	Time sampling
	Quick Exposure Check	Pen-paper	"Worst case" of the task
	6. Rapid Entire Body assessment	Pen-paper	Most common/ loaded/postures
	7. Washington State Ergonomic Checklist	Pen-paper	Screening for tasks
	8. Postural Loading on the Upper Body Assessment	Pen-paper, Video	Most common/ loaded postures
Methods for workload on upper limbs	1. Health and safety Executive (HSE) upper-limb risk assessment method	Pen-paper	Tasks involving high repetition/ low variety
	2. Rapid upper-limb assessment (RULA)	Pen-paper, video	No detailed rules
	3. Strain Index	Pen-paper	No detailed rules
	4. Occupational Repetitive Action	Pen-paper	Assessment of repetitive
	5. Washington State ergonomics checklist	Pen-paper	Items selected by caution zone checklist
Methods for manual material handling	NIOSH lifting equation	Pen-paper, computerized	No detailed rules
	2. Manual handling assessment charts	Pen-paper, video	Selection by general knowledge of work
	3. Washington State ergonomic checklists	Pen-paper	Worst & most common lifts
	4. Manual Task Risk assessment	Pen-paper	Rules stated in Queensland manual tasks advisory standard

Table 3-2 Observational methods with target exposure and advantages

Methods	Target Exposure	Advantages
General methods		
• Ovako working posture assessment	P, F	Generally used for documentation
• Posture targeting	P	Output is hypothetical, given measurement on ordinary scale is valid.
• Ergonomics Analysis	-	Computerized registered to analyze with illustrative output.
• Posture, activity, tool and handling	P, F	Helpful for making job specific templates and observation. Data are proceeded in automatic on computer.
• Quick Exposure Check	P, F, D, Fr, M	Easy to use. Easily can handle wide ranges of data, can interact with risk factor.
• Rapid Entire Body assessment	P, F	Rapid to used, computerized application is available for public use
• Washington State Ergonomic Checklist	P, F, D, Fr, M, Vib	Simple, quick, easy and record risk factors with duration and frequency.
• Postural Loading on the Upper Body Assessment	P	Simple, easy to use. Score is based on physiological data.
Methods for workload on upper limbs		
• Health and safety Executive (HSE) upper-limb risk assessment method	P, F, D, Fr, Vib	Easy to use, straight forward questions. Advice for solution.
• Rapid upper-limb assessment (RULA)	P, F, static action,	Easy to use. Computer application is available for public.
• Strain Index	P,F,D,Fr	Main risk factor is use for observe, can have comparison of jobs.
• Occupational Repetitive Action	P,F,D,Fr,Vib	Every recovery period can be noticed, can estimate risk level by repetitive movement, checklist is easy to use.
• Washington State ergonomics checklist	P,F,D,Fr, Vib	Simple, quick to use.
Methods for manual material handling		
• NIOSH lifting equation	P, F, D, Fr	Well documented, based on scientific studies, outcome is related to back, calculate can be done in internet.
• Manual handling assessment charts	P, F, Fr	Simple and easy to use. Well process for assessment
• Washington State ergonomic checklists	P, F, D, Fr	Simple and quick to use with risk factors with duration and frequency.
• Manual Task Risk assessment	P, F, D, Fr, Vib	Quick and easy to use for manual material handling.

*P=posture, F=force, D= duration, Fr= action frequency, Vib= vibration, M= movement

Table 3-3 Previous observational method with limitation and relation with MSDs

Methods	Associated in musculoskeletal disorders (MSDs)	Limitation
General methods		
• Ovako working posture assessment	cross-sectional studies	Left and right sides are not separated, neck and elbows/wrist postures are
• Posture targeting	-	Suitable for static posture only.
• Ergonomics Analysis	-	Much more time consuming.
• Posture, activity, tool and handling	-	It only account exposure level relative duration.
• Quick Exposure Check	cross-sectional studies	When task is varied frequently, then not suitable.
• Rapid Entire Body assessment	-	Assessment should be done separately on right and left.
• Washington State Ergonomic Checklist	cross-sectional studies	Limited to risk screening
• Postural Loading on the Upper Body Assessment	-	Doesn't consider force, duration
Methods for workload on upper limbs		
• Health and safety Executive (HSE) upper- limb risk assessment method	-	No measure to risk and observation item is not clear.
• Rapid upper-limb assessment (RULA)	cross-sectional studies	Assessment should be done separately on right and left side.
• Strain Index	Predicting in longitudinal, cross-sectional studies	Limited to upper risk assessment
• Occupational Repetitive Action	cross-sectional studies	Time consuming assessment.
• Washington State ergonomics checklist	cross-sectional studies	Limited to risk screening
Methods for manual material handling		
• NIOSH lifting equation	cross-sectional studies	Requires to measurement for skill and time estimation.
• Manual handling assessment charts	-	Use for only lifting, carry with frequency.
• Washington State ergonomic checklists	cross-sectional studies	Risk screening is limited
• Manual Task Risk assessment	-	Chosen subjective assessment

An overview of risk assessment and postural analysis is done and scored, taken into consideration in biomechanical load exposure by women in housework is described in the article “Loads of housework? Biomechanical assessments of the upper limbs in women performing common household tasks”.

A study in “Postural assessment of rural water fetcher using ergonomics” published in European Journal of Molecular & Clinical Medicine. The experiment was done in Structural Engineering Department, Veermata Jijabai Technological Institute Matunga, Mumbai, India. The conclusion of the study was to find the level of exposure and musculoskeletal disorders in body and giving a way to reduce the risk in the watcher fetching work.

A study in “The risk of musculoskeletal disorders for workers due to repetitive movements during Tomato Harvesting” was published on 2010 written by. The experiment was done in Italy. In this paper the conclusion was evaluate maximum number of recommended actions by upper limb and calculate the value of OCRA index which was greater than 20 but according to OCRA index the index should be less than 3.5. The trend was to replacing manual sorting onboard to reduce the risk of musculoskeletal disorders in works.

A paper titled “Vegetable grafting in greenhouse: the risk of musculoskeletal disorders for workers due to repetitive movement of upper limbs” was published in International Conference RAGUSA SHWA 2012 under “Safety Health and Welfare in Agriculture and in Argo-food Systems” showed that grafting work required actions on upper limbs having a no, of repetitive movements. The risk may involve in the body parts i.e., wrist, shoulder, carpal tunnel etc. So, the work is scored by OCRA index and it was 2.3 on the left limb situated is yellow zone which means there’s can be a possibility of risk. But OCRA index was 7.1 on the right limb which is not acceptable and should be taken into consideration as soon as due to red zone & high risk.

A paper “Preventing work-related musculoskeletal disorders in manufacturing by digital human model” published in International Journal of Environmental Research and Public Health 2020 concluded by presenting the result that the analysis by the human model is very useful if the workforce is bigger. So, taking advantages of the workplace doesn’t account the risk of WMSDs. Using ErgoMax system is implemented in 3D studio with detailed data for the assessment to get WMSD risk. The presented approached in the paper is not suitable sometimes, but worth checking having digital environment. Therefore, some limitations needed to be taken, as level of work experience should be pointed through the employee's view.

A paper titled "Domestic water carrying and its implications for health: a review and mixed methods pilot study in Limpopo Province, South Africa" published in Environment Health 2010, that highlighted the spinal pain with water carrying in South Africa. The spinal pain and its interfering with people's capacity to water carrying directly affected the potential with water availability in house. Here, in the paper is has shown that the methods of water carrying is observed due to which it came into conclusion that the physical loading make symptoms of musculoskeletal disorders and disability. The higher risk of injury among women and children which can be affected by poor health structure due to hazardous environments. Since water carrying is performed manually, it is quite different from other workplace and should be further analyze for future research. In this research paper, it has also stated that countries with poor, rural environment communities can lead to lower level of physical boundaries to be focused on. Some report has given data of potential risk factors of women and children who carries has complained of either neck or back pain or both [23]. It has also stated that the water that they carried can sometimes exceed tissue tolerance of human body [30,36,55,56]. This tissue tolerance depends upon the strength of the living tissue which also depends upon the nutrition, malnutrition, chronics illness, environment, poverty [31,57,58]. Loading capacity beyond strength can lead to changes in bone and tissues [12]. Therefore, future study should be investigated on the loading intensity, frequency, duration to know the exposure. Techniques on manual handing should be guided in such a way that it can lead to having good postures and comfortable for body [60,61]. It also stated that, sudden change in posture may lead sometimes to an injury due to high compressive force which can occurs due to muscle contraction in spine during work [11]. Rapidly changes in posture during rapid actions like lifting, carrying, manual handling can create higher force than threshold value of injury [11]. Identifying the risk factors can be helpful in reduce the risk and can be carried in such a way that in can concentrated and recognize the impacts on musculoskeletal problems.

4 RESEARCH METHODOLOGY

4.1 Research Strategy

An approach of mixed method was taken, that can bring out the both qualitive and quantitative data which we need for to better understand the performance and the experience of the participants of the experiment samples. Ergonomics assessment tools were used to collect the quantitative data. The study has used some known theories and well-known questions that verified the data. By ergonomics evaluation method, we evaluate the outcome of the research. Here, the computational visional method to analyze human motion also used. Because it helps to detect and track the joint. Tracking helps to get an estimated values of movement pattern.

Ethical Consideration: The recorded video was used for analyze the postures of villagers with the help of mechanics. So, to lower the anxiety of recording video, it is informed that recording was only for the project study and the recorded video will not be share, spread anywhere or will not be seen without the consent of the participants. Before anything was performing, it was made sure by us that they have individual consent and no harm would be cause to them. After the study, it is our duty to delete all the video recordings of them in order to protect the materials if the participant ask us to do so.

4.2 Participants

A sample were recruited consisted by 5 people or villagers as subject participants for the preliminary studies. Then 24 females were recruited for the final study using kinematics analysis and posture analysis by using some assessment tools. These 24 females and their female family members were taken into consideration for Nordic Musculoskeletal disorder to get information for musculoskeletal disorders related problems. These 24 females were aged of 12-52 years, with average height 153.544 ± 6.19 cm and average weight 47.47 ± 8.48 kg. They have no records with neurological diseases and hereditary diseases of psychological medical unfitness. They were as usual healthy. The study was done in a village of Jhargram, West Bengal.

4.3 Sample Selection

Since in the study all the participants have to go through a certain level of instructions to get rid of the all the unnecessary things that might increase the inaccuracy of the analysis of the experiment. That's why some certain types of inclusion and exclusion has to be done. The people who are included in the study are noted as –

- Participants has to be females or teenager of any age.
- Individuals have to be the residents of that particularly village.
- Participants who have participated in fetching should be doing as it is a part of their daily life.
- Individual used their own well or other's well to collect water.

The people who were excluded from the study –

- Those who are too old or greater than 60 years old.
- Those, has no knowledge or experience on fetching and carrying water.
- Those who transport water using vehicles, cycle, bull-cart.

4.4 Experimental Set-up

The experiment was conducted in the village. The apparatus and their location are illustrated. For water fetching, a simple set up was done. Either one of the sides of the participant was focused and recorded for data collection by mobile.

4.5 Procedure

The procedure of the experiment is consisting of three parts is given following –

- Interviews.
- Observational methods.
- Evaluation methods.

4.5.1 Interviews

Interviews are different according to work environment and work methods; structured, semi-structured and unstructured. The structured interviews contain a prepared questionnaire that have predetermined questions and some rooms for upcoming questions. Semi- Structured interviews contain a lot of room for small questions. This gives interviews a depth of knowledge and experience that he/she can get from the participants and if possible, she/he can be got in the depth on certain parameters and areas. Unstructured interviews consist no standard, predetermined, a set of questionnaires. It is performed with little organization or can be start with open, comfortable questions or can be performed depending upon the answers. Therefore, unstructured interviews are very much difficult to manage without the proper guidance, not only for the interviewer but as well as for the participant. and time consuming which is disadvantages for research strategy.

The interviews are useful because they were completement to the observations and helps us to understand the performance and can see the view to that point as the participant said. The interviews were done using Standard Questionnaire (Appendix I). Interviews were taken in the work time, after the performance and lasted approximately 10 minutes each and every individual. The analysis of the data of the questionnaire was done using Microsoft Excel.

The interviews were done after considering some following information –

- Participant's personal data such as age, height, weight and past serious health related history.
- Daily work hours- profile, house chores works-hours.
- Pain/discomfort in the different body regions and it is done by using modified Nordic Questionnaire by Kuorinka et el., (1987).
- Psychological work factors were measured through the questionnaire model by Karasek and Therorell (1990) (Appendix II). These questionnaires were chosen because some of them are interrelated and the checklists were there to help little bit aspects of work. The questionnaire was chosen because they are structured with "yes" and "no" rather than scale ranging from 0 to 5 points which is equivalent to "poor" to "extreme". Therefore, the advantages that we get is that we interviewer and

participant got very easy to answer and time saving. With the taking into consideration, these interviews were done and conducted during participants' work time.

Other than the above questions, some detailed questions were asked to individual male and female of the house to understand their psychological factor towards water fetching such as,

- Do you have any other sources of water collection?
- When the first time did you start water fetching? From then to now, what do you think has change?
- What are the problems do you face during your daily life while pulling water out of wells i.e.; pain in the shoulder joint, elbow joint, waist or abdomen pain, hip join and legs?
- Does the load changes from time to time? If yes then consider the load ranges
- Did you had to work even you were in your pregnancy? If yes, why?
- If you are having chronical pain, then do you go to the doctor immediately or not? If no, why.
- Does water fetch particularly effect on the menstrual phase?
- Can you tell me about your total water collection experience?

4.5.2 Observational Methods

Two-dimensional recording procedures

The following steps have been used with consideration to have minimum errors during videography, improving accuracy of data. This method is very helpful to students who are very much unaware of videography and it allows a simple linear transformation.

- The optical axis of the camera should be perpendicular to the human motion.
- The camera should stay in steady mode such as no tilting or any other movement rather than capturing motions.
- The camera should be at a distance from the action of the participants.
- Before recoding, the camera should be adjusted its focus to the image and from the start to end of the video recording, the focus should not be lost.

- If auto focus option is available, then it should be turned on if forgot to turn on or turn off manually.

- No works need on the background so, it is okay until and unless the background create noises, reflection and distortion for the focused human motions.

- Calibration is needed for the field view.

In the fig.4.1 a block diagram is shown for these proposed observational methods. At first, we need to set camcorder with the participants. Participants were fetching water out of the well while she will be recorded under 2D camera in X-Y plane. In the second step, the recorded video will be transferred to the computer and use Kinovea software to save as .kva extension files. In Kinovea software manually tracked the body-joint by per key image in Kinovea. In the same way we track the inside angles in the joints by per key image. Then in the next step, the recorded data is exported in the spreadsheet. Then, the position, displacement, velocity has found out.

Figure 4-1 Posture during water collection

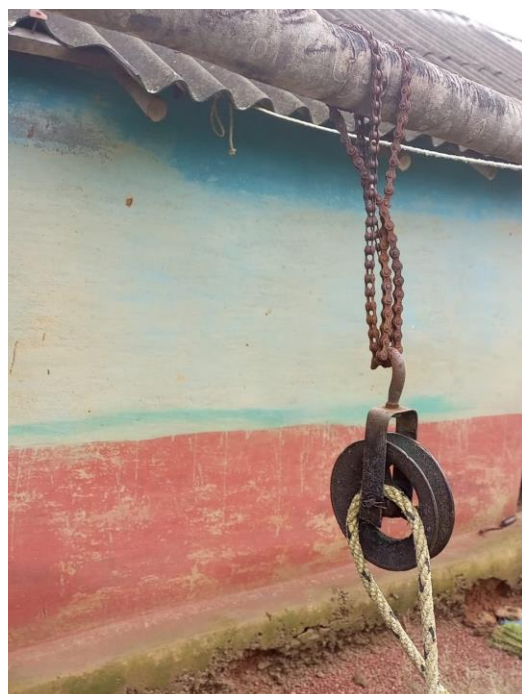

Figure 4-2 Usable pulley for water collection

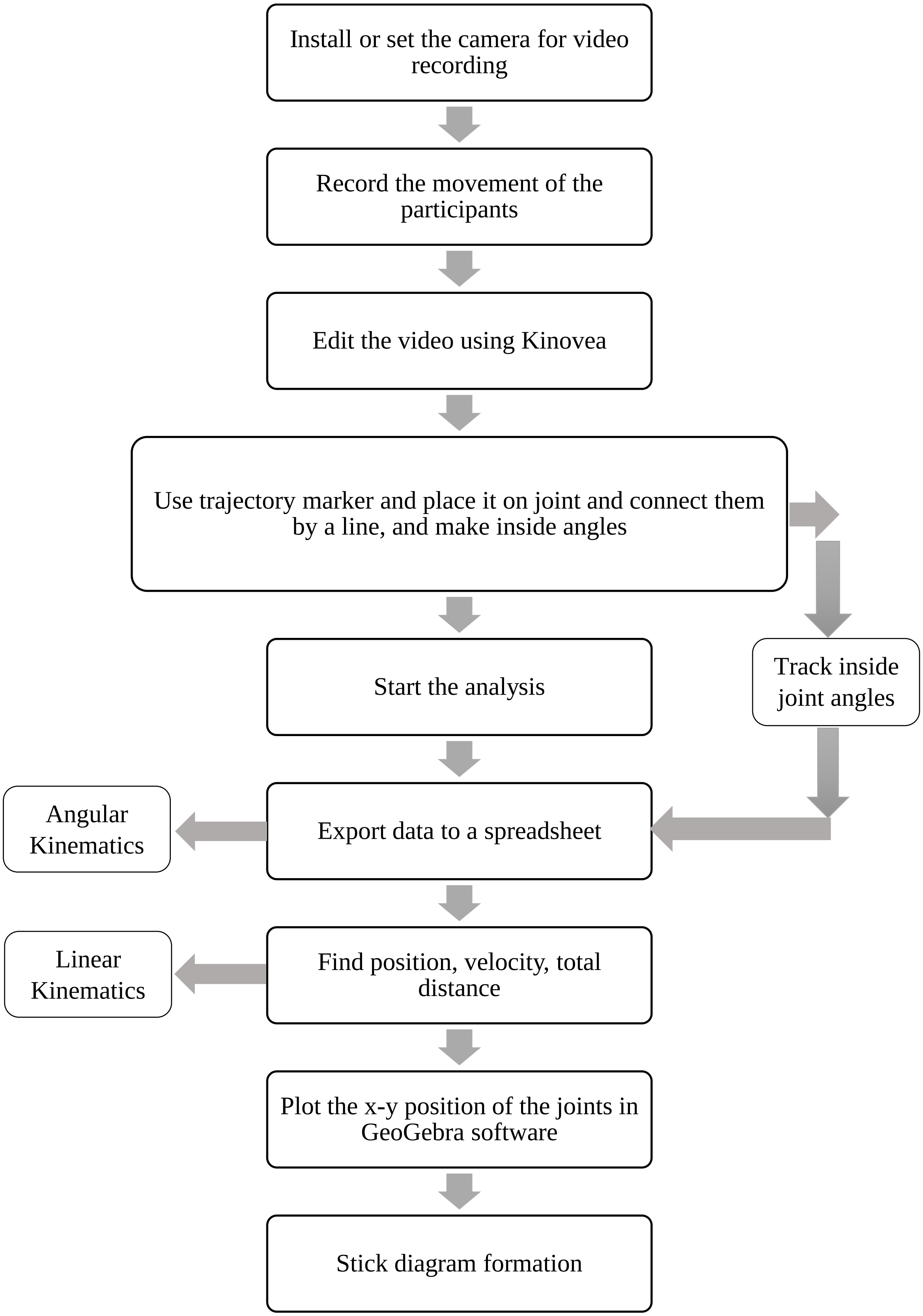

Figure 4-3 Block diagram of data collection for human motion analysis

4.5.3 Data Processing

4.5.3.1 Image Processing

1. **Setting a Coordinate System**

To give command to KINOVEA software to track path and track kinematics parameter in the normal running video, we need to command the software to have a common coordinate with the video so that it can detect. Here, the coordinate system will be in the shoulder joint (0,0). Therefore, the coordinate position of the each and every joint of the human body is detected by the software and it is changes in centimetre (cm) from pixels (px).

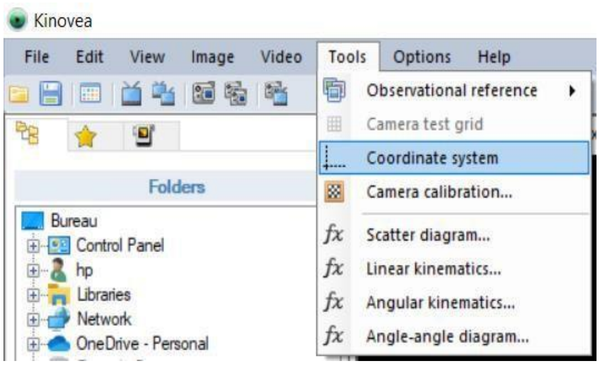

Figure 4-4 Setting a coordinate

2. **Tracking motion using Kinovea**

Kinovea software is an open-source software that was helpful to get all the output of images and videos from the mobile storage where the videos were saved in 1080x1920 px. Then, all the videos (files) were first undergone checking whether there were any errors or not. If no error found, then the videos are ready to edit with Kinovea software. Low quality pictures or any kind of distorted pictures were discarded. So, next if no any other errors were found then it is accepted on which the marker tracking for motion will be done. Therefore, the following steps has been taken –

Step 1: Choose the object to track

Right-click on the mouse in the video upon the object where you need to locate the marker, then choose “track path". A coloured cross box will be appeared over the position you choose. We can change its position if we like.

Step 2: Tracking

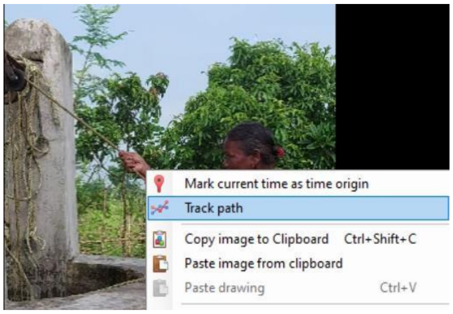

Figure 4-5 Tracking

Kinovea software has very big advantage on tracking as it can track any object automatically as per key image or frame by frame of the video. But also has disadvantages as it is much time consuming. We can manage to correct tracking position if somehow markers cannot recognize the object due to haziness. Therefore, the marker is being dragged by the cursor in each frame of the object movement.

Step 3: Calibration

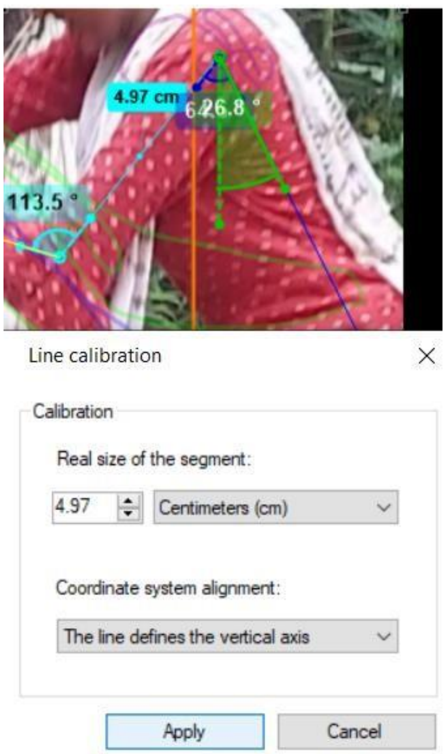

Figure 4-6 Calibration

For measuring speed of the object, we have to calibrate the scale of the video image. Therefore, if we have already calibrated the measurement before tracking as setting coordinate then there will be no issue, if not, then after pressing “line” from task bar and drag it vertically from feet to head as the sample’s height and then adjust it more accurately by allowing zooming in at 600%. Then give the line a name “Height" in configuration menu by left click. For the both cases we need to have actual measurements of the clip of 1080x1920 px in cm. Then by clicking right on the mouse, we get menu and click on “calibrate measure". Then enter the actual measurement of the height (in cm) or otherwise you can put the height (changed from px to cm) as I did here. Therefore, I got the height in ratio which was not actual. I changed it in excel file before making stick diagram. So, after putting the value, I needed to define the axis on which the coordinate system aligns. Then left click on “apply" button. After doing it so, every segment is then calibrated.

3. **Angle Measurement**

Since the working movement is the perpendicular to the optical axis of the camera. So, it is known that no angles will be distorted.

Step 1: Create body segment

Create “line" after clicking on “line” from the taskbar. Then connect the body segment at joint marker. It is the first thing that need to be done for angle measurement.

Step 2: Create angles

left click on the “angle" icon in the task bar. Then, click on the joint where you want the inside angles of two body segment. Need to drag the angle segment if needed to align with the joint marker and body segment line.

Step 3: Tracker on

Right-click on the angle and go to configuration and name it i.e., shoulder angle, then right click again on the angle and turn on the visibility by clicking on it and turn on the tracker by clicking on it. The tracking procedure is same as motion track path. The tracking phase goes on frame by frame in every key image.

4.5.3.2 Self-Processing

Force and Coefficient of friction of the pully measurement

Step 1: Load measurement of bucket (with and without water)

First set the Spring balance in “kg" unit and then attached one side of the spring balance on the bucket and hold another side of the spring balance, then see the ratings and written it down. Same is done for bucket fill with water.

Figure 4-7 Weight of the empty bucket

Figure 4-8 Weight of the filled bucket

Step 2: Force measurement in hand

Set the spring balance to "0" and "kg". And then connect the hook side of spring balance on the rope and hold the other side on the one hand after filling the bucket and pull it on the towards the body. Then see the rating and write it down.

Step 3: As we get the load with bucket fill in water (F_1) and the force made by hand (F_2) while puling of the first subject, and the wrap angles from angle measurement, then we can get the co-efficient of friction (μ) between the pulley and the rope.

Step 4: as we get the coefficient of friction, keeping it constant we can get pulling force for others as from angle measurement technique we can get the wrap angle.

Figure 4-9 Spring balance load collection

4.5.4 Evaluation Methods

To understand the posture presentation of the participants a certain level of evaluation methods was taken into consideration. When the data was collected for the project, it was under consideration having few methods and try them for trial and then completing individually afterwards. All the methods were done separately and also discussed it with the participants because there are some considerations that can be answered by the participants. This was because of the participants' point of view to perform in a better way and complete with inexperience throughout the methods. Not all ergonomics assessment was done to evaluate. While evaluating through the participants point of view it is very much beneficial to this project. The methods are used as per keeping its own limitation and strengths e.g., RULA (Rapid Upper Limb Assessment) and REBA (Rapid Entire Body Analysis) and ART (Assessment of Repetitive Task)

4.5.4.1 RULA (Rapid Upper Limb Assessment):

It is a posture assessment tool that focus on the upper body like hand and arm. The method is easily designed that it does not need any other instruments and machine (Ergonomics Plus, 2016). For this assessment Sagittal view is considered. For right and left side, the assessment is done separately. So, for the evaluation we have to give score for postures. From the spreadsheet that was export from Kinovea, first collect all the angles and find out the maximum, minimum and average angles of each inside angles and as well as their postures. The steps that are taken for the RULA assessment to give score the postures –

There are two part of analysis, part A use for analysis of arm and wrist. It is included from step 1 to step 8.

Step 1: we have to measure the upper arm angle. The inside angle between back and shoulder/upper arm is considerate here. According to the posture there is a score. If the upper arm is having angle between 20˚ then "+1", if the upper arm is extension or having angle between 20-45˚ then "+2", if upper arm is in forward having 45-90˚ with back is "+3" and if the upper is having more than 90˚ angle which means it is raising upward then the score will be "+4".

Here, some adjustment is done, such as if the shoulder is raised the add +1, if upper arm is abducted add +1, if person is leaning or supported then subtracted -1.

Step 2: Here, lower arm or forearm position is focused. If the inside angle between forearm and upper arm is between 80-100˚ then, add +1. If more than 100˚ then score it as +2. The adjustment with +1 if the person is crossing his arm at midline or out of the body.

Step 3: The wrist position is concentrated if it is neutral then +1. If it is deviating from midline with 15˚ then +2. Adjustment with +1 if wrist is ulnar deviation.

Step 4: If the wrist is twisting in mid-range +1, if trying to cross range of motion then +2.

Step 5: Analysing the score from arm and wrist, we find the score from Table A.

Step 6: Here, muscle score is added. Muscle score is given as per posture. If the posture is mainly static holding at least 1min with the same position then score to be added is +1 or if the action is repeated occurring 4times in a 1min the also add +1.

Step 7: Add the load/force according to weight given by standard chart. If load is lower than 4.4 lbs with intermittent, add +0. If the load is between 4.4-22lbs with intermittent add+1. If the load is between 4.4-22 lbs but repeating then add +2. If the load is more than 22 lbs repeating then add +3.

Step 8: Now add all the score get form step 5, step 6, step 7. And note down.

The second part B is including neck, trunk, leg analysis.

Step 9: The neck angle is had to collect from the video and if the neck is in neutral position from 0-10˚ then ads +0. If is in extended forward with range of 10˚ to 20˚ then add +2, if more than 20˚ extended then add 3. If the extension is in backward then add +4. Adjustment is done by if neck is twisting then add +1. If neck is side bending, then add +1.

Step 10: The angle of trunk which is measured from the vertical axis to back, if the angle is in neutral then +1. If then angle is between 0-20˚ then add +2. If the angle is between 30-60˚ then add +3. And if the angle is more than 60˚ then add +4. The adjustment is if the trunk is twisted then +1. If the trunk is in side bending, then +1. By viewing all the possibility, score the trunk.

Step 11: If the both legs are supported with equal balance then +1, if not then add +2.

Step 12: From the table B, with the score of steps 9, step 10, step 11, get the posture score.

Step 13: Same way as per step 6, add the muscle use score.

Step 14: Same way as step 9, add the force/load score.

Step 15: Add the score of steps 12, step 13, step 14. And note down it.

Now, from the part A, score of steps 8 and from group B, score of steps 15 is evaluated in Table c. And the connecting score lies between group A and group B is said to be the Final score of the RULA assessment.

These RULA assessment score is divided in 4 division. Scoring is from 1 to 7.

If the final score lies between 1 or 2, then there is no problem with the posture.

If the final score is lies between 3 or 4, then change may or may not be needed.

If the final score is 5 or 6 then investigation should be done and change needed.

If the score is 7 then implement should be done as soon as possible.

For example, one study is shown in the ergonomics RULA Employee Assessment Worksheet.

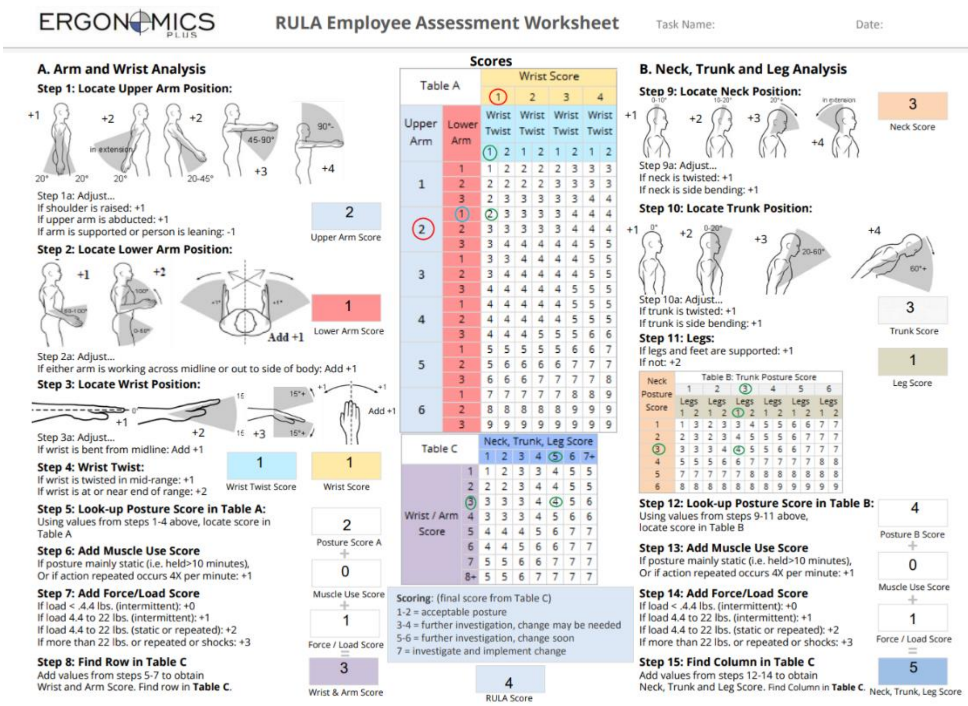

Figure 4-10 RULA assessment

4.5.4.2 REBA (Rapid Entire Body Analysis):

REBA is also uses like RULA but it is much more focused on the whole human body (Osvalder, Rose and Karlsson, 2015). It is also having two parts – Part A: Neck, Trunk, Leg analysis and Part B: Arm & Wrist analysis. REBA consider load on the body as well as coupling score. Like RULA, REBA method is to generate score that determine to recommend what kind of action should be taken for risk management. Like RULA, it also can be done separately for right and left lateral view. It also has activity score which is considered as factors for doing task. Even though this assessment is similar to RULA, but the factors of REBA mostly depend upon Coupling effect. The steps that are taken to reach the posture in REBA is given below –

Step 1: Same as RULA, with different score, the neck angle is had to collect from the video and if the neck is in neutral position from 0-20˚ then add +1. If is in extended forward with 20˚ or more then add +2. If the extension is in backward then add +4. Adjustment is done by if neck is twisting then add +1. If neck is side bending, then add +1.

Step 2: The angle of trunk which is measured from the vertical axis to back, if the angle is in neutral 0˚, then +1. If then angle is between 0-20˚ (bending forward) then add +2. With forward bending angle between 20-60˚ then add +3. And if the angle is more than 60˚ then add +4. With backward bend in extension then add +2. The adjustment is if the trunk is twisted then +1. If the trunk is in side bending, then +1. By viewing all the possibility, score the trunk.

Step 3: Leg score is done, if both legs supported then +1, if not then +2. The adjustment with if the knee angle is between 30-60˚, then +1, if more than 60˚ then add +2.

Step 4: From the score of steps 1, step 2, step 3, evaluate the posture score from table A and note down.

Step 5: Here, same as RULA, add force score. If the load is less than 11 lbs then add +0, if load is between 11-22 lbs, add +1. If the load is more than 22 lbs +2. Adjust it with of the load is rapid or shock, add +1.

Step 6: Add the score from step 4, step 5 and note down for the evaluation in Table c.

Step 7: We have to measure the upper arm angle. The inside angle between back and shoulder/upper arm is considerate here. According to the posture there is a score. If the upper arm is having angle between 20 then "+1", if the upper arm is extension or having angle between 20-45˚ then "+2", if upper arm is in forward having 45-90˚ with back is "+3" and if the upper is having more then, 90˚ angle which means it is raising upward then the score will be "+4". Here, some adjustment is done, such as if the shoulder is raised the add +1, if upper arm is abducted add +1, if person is leaning or supported then subtracted -1.

Step 8: Here, lower arm or forearm position is focused. If the inside angle between forearm and upper arm is between 80-100˚ then, add +1. If more than 100˚ then score it as +2. The adjustment with +1 if the person is crossing his arm at midline or out of the body.

Step 9: If the wrist is having up and down deviation with angle of 10˚ then add +1. If the deviation is more than 10˚ the add +2.

Step 10: From the score of step 7, step 8 and step 9, find the posture score from Table B and note down.

Step 11: Add coupling score. Coupling score is depending upon the grip. If it is well fitted grip then add +0 (good). If the griping is acceptable but not ideal or coupling is accepted with other body part then +1 (fair). If the hand hold is possible but not accepted, then add +2 (poor condition). If the griping condition is awkward unsafe then +3.

Step 12: Add the score from step 10 and step 11 and write down.

Step 13: Score from step 6 of part A and score from step 12 from part B is used and evaluate the Table C score.

After the table c score, we add it with activity score. Activity score is depending like, if one or more body part is held longer than 1 minute with static position then add +1. If the repeated action occurs 4 times in a minute, add +1. If action causes rapid change of posture, then +1. After adding activity score, we get the final REBA score.

REBA score has some range with its exposure and investigation, such as; for negligible risk, the final REBA score has to be 1. If the score is 2 or 3 then, low risk. If score is between 4 to 7 then risk is medium, further investigation may need. For score between 8 to 10, high risk is there, change of implementation. If the score is 11 or more than 11 the, the risk is pretty much high and the implementation is should be done as fast as possible.

For example, one data is shown in here about the steps and scoring of the human action. With the safe scoring, REBA assessment chart is given in figure 4-11.

4.5.4.3 ART (Assessment of Repetitive Task):

ART (Appendix V) too is used for determining the upper limb disorder. It is mostly used when the body movement is repetitive and frequent. Therefore, it is used for introspecting. It can identify where the risk is involved and how to reduce the risk. The assessment can be done separately for left side and right side. For this assessment some of the questions were asked verbally. It is also an additional score tool like RULA and REBA, here, the same concept is taken and that is if the score is high then the risk exposure level is high. There are

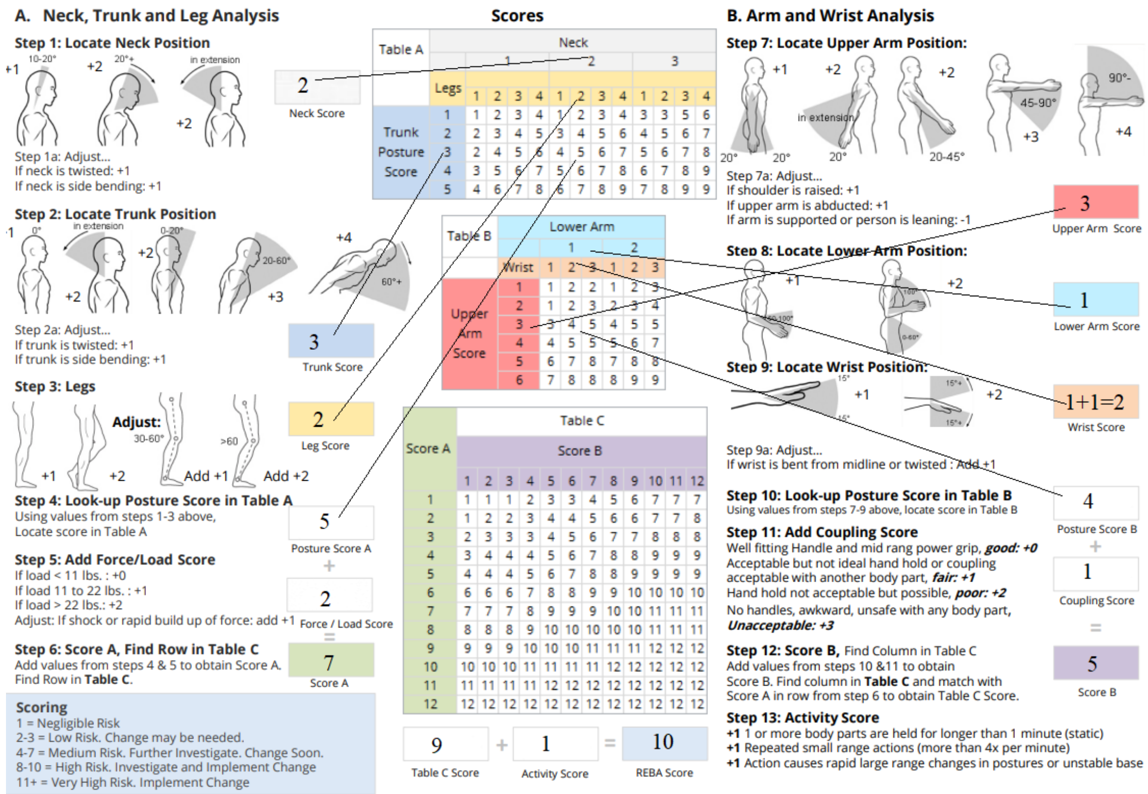

Figure 4-11 REBA assessment

some colour codes are given for knowing the risk exposure. For no risk with low score is ‘G’(green), for medium risk, ‘A’(Amber), for high risk, ‘R’(Red).

Design of ART assessment tool is done considering 4 stages and these are –

Stage 1: here arm movement frequency (A_1) and repetition (A_2) are involved. For A_1, if it is infrequent the G=0, if frequent then A=3, if very frequent then R=6. For, A_2, if it is repeating max. 10 times in a minute, then G=0, if repeating 11 to 20 times in a minute then A=3, if repeating more than 20 times in a minute than R=6.

Stage 2: here force (B) is determined by using interview and the time it is exerted. The force is considered by either light (no effort at all), moderate (pinching, pushing, pulling, using some effort), strong (force is high, strong also heavy), very strong force (the max. anyone can apply). For better understanding an appendix is given.

Stage 3: here, all the awkward postures has been determined with score. For head/neck (C_1), if it is in neutral then G=0, if twisted or bend for half of the time and most of the time then

A=1 and R=2. If Back posture (C_2) is in neutral then G=0, if it is bend forward or twisted any side for little time the A=1, for the most of the time it is R=2. For arm posture (C_3), if is close to the body, supported then G=0, if is away from body for little time then A=2, if more than that then R=4. If wrist posture (C_4), is in neutral almost, then G=0, otherwise if bend or twisted for little time then A=1, for more than half of the time it is R=2. For hand grip (C_5), if it is power grip then 0, if griping is liking pinching for half and more than half time it scores as 1 and 2.

Stage 4: Additional factor like – breaks (D_1), if continue working with small breaks then 0, if working every 1 to 2 hours with a break then A=2, if working 2 to 3 hour then A=4, if working more than 3 to less than 4 hour then R=6, if working more than 4 hours then, R=8.

- Workspace (D_2), if workplace is good and no difficult with doing work than 0. If sometimes difficult to do the work, then A=1, if too much difficult often then R=2.
- Others factors (D_3) includes like compression in skin while doing work, task requires precise movement in hand and wrist, gripping is difficult, numbness while working etc. can affect a human body, if no factor is there than G=0, if one factor is present then A=1, if two or more factors are present, then R=2.
- Duration (D_4): here, duration multiplier will be multiplied with the task score to get exposure score. So, if a person does repetitive for less than 2 hours then multiplied the total score by 0.5, if 2 hours to 4 hours then, multiplied but 0.75, for 4 to 8 hours, multiplied by 1, for more than 8 hours, multiplied by 1.5.

$$Task\ score = A_1 + A_2 + B + C_1 + C_2 + C_3 + C_4 + C_5 + D_1 + D_2 + D_3$$

$$Exposure\ score = Task\ score\ \times Duration\ multiplier$$

The interpretation of exposure level due to score is given below table –

Table 4-1 Interpretation for exposure level of ART assessment

Exposure score	Proposed exposure level	
0–11	Low	Consider individual circumstances
12–21	Medium	Further investigation required
22 or more	High	Further investigation required urgently

Here, a flowchart of ART assessment is given with safe score –

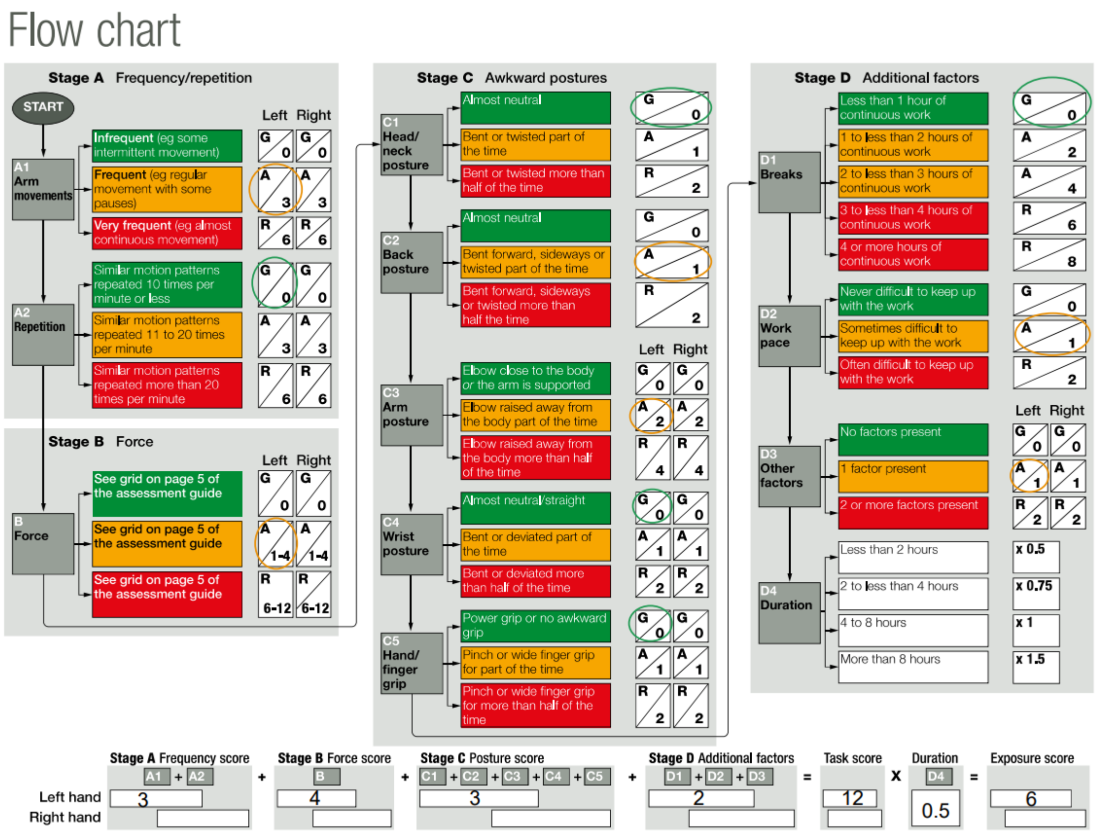

Figure 4-12 Flow chart of Assessment of Repetitive Task

4.5.5 Human Motion Analysis

4.5.5.1 Motion- based diagnosis and identification

To control the gripping in hand, motions are transferred to that hand by the whole body made up by kinematic chain to the hand. So, it is useful to identifying various body segments of human body throughout the image and make a sequence of performance pattern under 2D structure image and then, if possible, maybe, for future rehabilitation, by the simulation or computational modelling in 3D model can be useful. Now a days throughout the technological data and with the help of Artificial intelligence numerous tremendous jobs has been focusing on. And for this type of future scoring efforts can sort out people with disabilities and can help them to rehabilitate.

The movement analyst becoming growing arrays. The movements and their requirements of analysis determines the camera systems of choices. Standard video can provide at least 30 resolve pictures per seconds which is needed perfectly as needed for studying human movement analysis. For the quantitative studies and clinical research methods for human movement study, human motion requires more and higher quality levels of camera such as high-speed camera with frame rates up to 2000Hz. Consideration also follows for having proper camera speed so that it can create clarity over capture images. The camera's shutter speed that starts the length of time while video record was taken. As much as faster them movement analysed, the lesser exposure time is required. Another consideration about the video is that, because of the most movement doesn't constrain in a single plane so it is better to connect and use multiple cameras to ensure to understand and accurately image processing is done. But here in my project work, only one camera was used in xy plane because in this case, one sided movement was needed to be followed. And since the human motion was perpendicular to the optical axis of the camera, therefore the angles in the joint that were presented by tracking methods were not distorted but the height of the participant's and the length of the body segments was in the ratio format of the video image.

Identification of postures during preparing and lifting

Preparing: As in the given figures, we can see that the relaxation in the lower limb but their could be any muscle imbalances that could be ignore by the performer. The muscle imbalance in the body such as i.e.; gluteus maximus, gluteus medias, flexor hallucis longus. The angle in the hip joint is very important and taken into consideration since center of gravity of females generally lies between the pelvic.

Figure 4-13 Head/neck movement during preparing for water lifting

Lifting: During lifting two hands pulles the rope alternatively. Using kinovea software we get the picture of 2D postures, linear kinematic values i.e.; horizontal position,vertical position, speed, displacement etc. But here, because of 2D posture detector it is less possible to understand the imbalance between the shoulder, pulling force, ground reaction force. The instant changes in in angle and displacement, hip position in body can lead us to analyze the compression and tension in body joint by getting free body diagram. If the pulling force is different in the two hands then the stress will act differently on the upper body. And the body will try to balance the extra load can be causing muscle disablity. Here in the light blue line showing the total movement while lifting from the well and the angles in the joints are given and the thin lines between the light blue line and light orange line shows the dispacment of joint.

Figure 4-14 Body movement pattern during lifting

Joint displacement and velocity

Joint displacement and velocity are the most basic movement. As the data of joint was exported into spreadsheet. It has x and y axis position of body joint with respect to real time. Since the actions were perpendicular to the optical axis of camera so, the length of the body segment changes. So, calibration should be done before making any conclusion. And if the calibration is already done then the data are ready to be further study.

As the joint position is defined at the particular time, then it is used to get its relative position as per reference frame. But since the origin is already designated, therefore, for describing motion based on video, we use reference frame relative to origin.

Since, the joint moves relative to a reference frame, so, its position changed. It is displacement of the joint.

Since, the position of joints changed their position with respect to reference, it also travels with respect to time. Therefore, the velocity in the horizontal and vertical direction will be there and it also changes relatively frame. Here, the subinterval of the time is same.

So, after getting the position in the excel sheet, the positions of each joint are plotted in the GeoGebra. And connect the point through a line, therefore, we get the stick diagram of the fetching water.

4.5.5.2 Kinematic model visualization

Stick Diagram

Stick diagram or stick figure model is one of the human motion models that presents a simple diagram for getting a rough idea of human motion. The stick diagram was made in a plotting software called GeoGebra. The position exported in spreadsheet was written down the values in the GeoGebra manually. After the point was plotted, by the line, the point was connected to get body segments. Therefore, it can be estimated how the joints, are moving in a cycle with respect to each other. This type of representation is directly related to human body movement, human actions in the sagittal plane. The projection of the movement pattern is nearly perfect; therefore, it can be used for analysis further. Stick diagram gives the complete configuration of the participants joints, their connection and the size of the body segments. It also has some disadvantages. Since, stick diagram cannot represent muscle movement or rotational movement, for these 3D models is used. From the stick diagram, we can get the inside angles between to two body segments in joint. The conclusion from stick diagrams that are made are given in the Result section.

5 RESULTS

The results are drawn based on the different evaluation methods such as standard questionnaire, ergonomics methods, stick human model methods and joint displacement and velocity. The results are varying differently person to person. The questionnaire session was done for t5 persons. And the other methods were done for 12 participants to to take their videos and evaluated. The results of each session are given below –

5.1 Questionnaire

The results that we get from the Questionnaire is the results we found through interview. A demographic information that holds the key to the information regarding participants is given below –

Table 5-1 Shows the demographic information with no. of repliers n=25

	Age	Height	Weight	BMI	No. of collection
Minimum	13	144.6	32.05	16	9
Maximum	55	168	65	28.6	30
Mean	38.04	153.544	47.4708	20.16	17.64
Standard deviation	12.12944	6.193618	8.478601	3.133156	6.08194

From the chart, it can be seen that the maximum no. of the collection done is 30 times in a day. Therefore, it can be contributed to water for drinking, bathing, and using for house chores. So, daily working like these and collecting every 3 to 4 hours for need of water is normal for a normal house. But there are some housewives who work at their own home and open a little food stall in villages or sell drinking liquor that need water for work. So, they might have to work more extra and collect water than normally they need to do. So, even they work for little time, but their working condition can lead them to have musculoskeletal disorder. So, in the next, health risk information is taken for knowing their problems.

5.1.1 Health risk information

Participants were asked through the interviews, about their postural discomforts and pain lasted at least 24hours, 7 days or a month to find out more knowledge about the postural problems. Those results are presented here.

The Figure of discomfort or pain lasted for 24hours is given here –

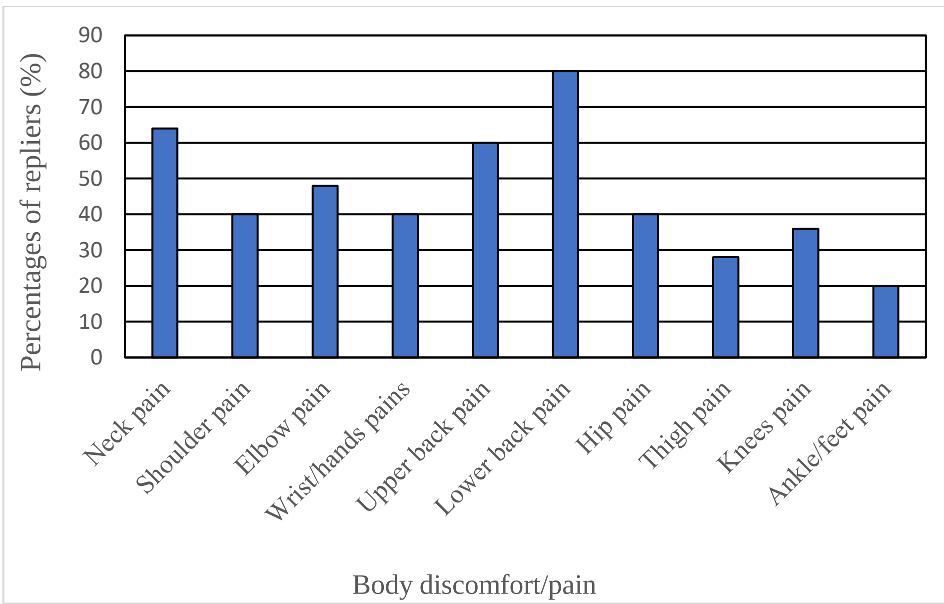

Figure 5-1 Discomfort or pain lasted for 24hours

In the last 24hours, 16 out of 25 (64%) of the women had neck pain. About 40% (10) had shoulder pain, 48% (12) had elbow pain and 40% (10) had wrist pain that lasted at least 24hours. 60% (15) of the respondents include that they had upper back pain and 80% (20) women complained that they were suffered from lower back pain. 40% (10) were said to have hip pain and 28% (7) were suffered from thigh pain. For knee pain 36% (9) said to suffer and for ankle pain only 20% (5) said to have it.

The figure of body discomfort/pain lasted for 7 days is given below –

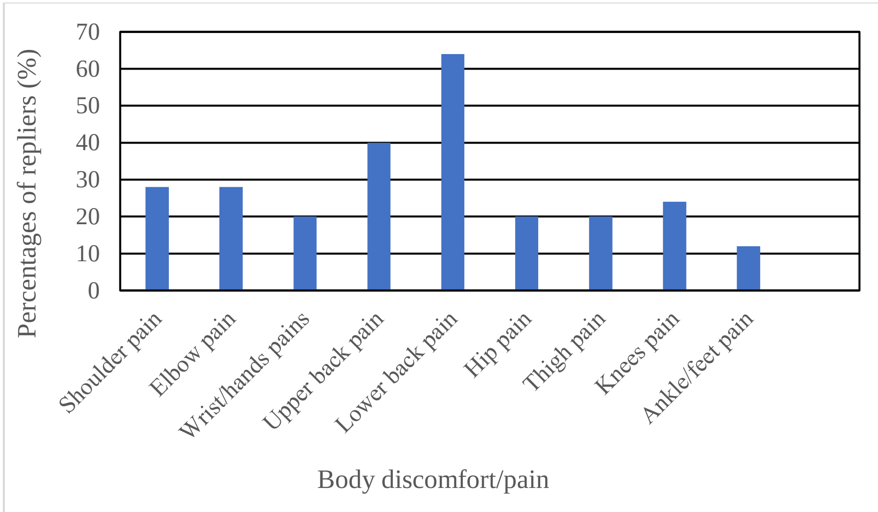

Figure 5-2 Discomfort or pain lasted for 7 days

In the last 7days, the no. of complaint from respondents' changes. 9 out of 25 (36%) of the women had neck pain. About 28% (7) had shoulder pain, 28% (7) used to have elbow pain and 20% (5) had wrist pain that lasted maybe 7 days. 40% (10) of the respondents include that they had upper back pain and 64% (16) women complained that they were suffered from lower back pain throughout the 7days. 20% (5) were said to have hip pain and 20% (5) were suffered from thigh pain. For knee pain 24% (6) said to suffer and for ankle pain only 12% (3) said to have it (figure).

The figure of body discomfort/pain lasted for 30 days is given below –

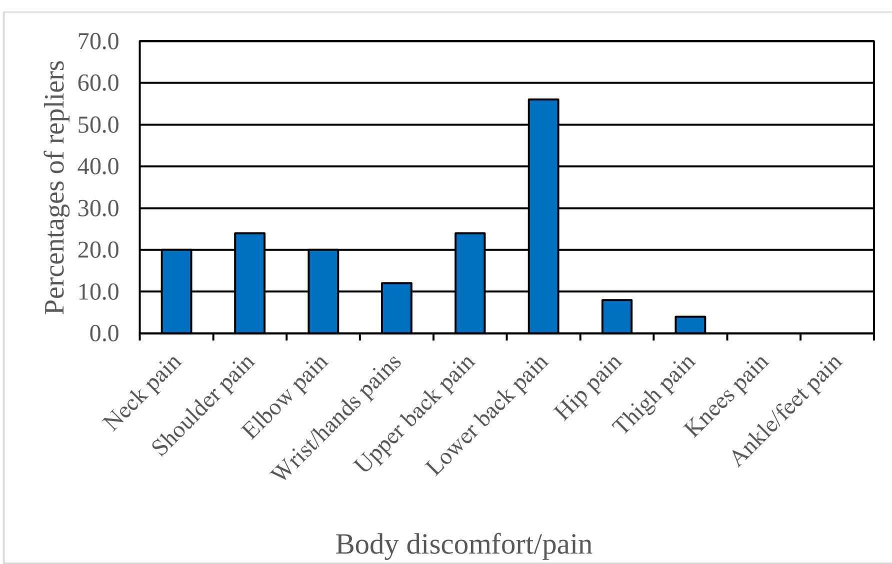

Figure 5-3 Discomfort or pain lasted for 30 days

In the last 30 days, the suffering responds changes very much but lower back has its effect. 56% (14) women has complained about lower back pain and 24% (6) suffered in upper back problem. 25% (5) of women complained pain in the neck and elbow. 12% (3) only on the wrist pain. Hip pain and thigh pain was concentrated by 8% (2) and 4% (1). No complaint was found regarding knees and ankle problems.

5.1.2 Daily Life & Equipment Factors

Housewives from every family has to collect water whether for their children, their works and their works. The water they collected in the bucket have a weight of nearly 5 kg to 10 kg, but the water they use higher than 50 litres. Waking up at morning, then continue working for family, business, then house chores in non-quality life lead already tiredness. But still they have to work lead the body already fatigue. And collecting water again put stress on the joint. Continue working without taking rest makes body to be in risk.

5.1.3 Individual Factors

"Water collection for household chore is a woman task, it's their responsibility, that's what they should do. There are less chances that we man collect water, we only do it when our wives are ill, but sometimes when it necessary we collect them for ourselves. We collect water when we need water for bath, clean the dishes."

5.1.4 Psychological Factors

Some anonymous questions were asked to know their psychological point of view regarding their working factor. All of them described it (the work) as "hard but need to do" since they have no choices. They were bound to do so from very little they were. The working function need more and more power and strength but it is all okay because they have learned to manage it. Pain and discomfort might come in their way to work but because of the poverty, they can not go to doctor until it become serious injury. At first, there were discomfort and pain in the body but later it becomes normal. Most of the time the pain grows in the waist, back region but after taking rest for a while, the pain gone. So, no need to watch out for doctors. Working in such environment where muscle fatigue is there can be harmful but they think it's okay to work since males are not going to help them anyway.

5.2 Ergonomics Result

5.2.1 RULA assessment Result

RULA assessment score is different for every participant, however, some of the scoring has been done assuming after reviewing the task more than 5 to 6 times, then came to a conclusion of scoring. Posture A and Posture B is used. Posture A is the combination of Arm and Wrist analysis. Posture B is the combination of Neck, trunk, and leg analysis. The only adjustment is done for upper arm position, no other adjustment is done for body. The assessment scoring process is done as per given below –

For person 1, *i) Posture A*: The upper arm average angle is 67.59˚±28.01˚. So, the score is +3, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle of flexion is 90.54˚±22.78˚, so the score is +1. From the observation, the wrist is deviating with 15˚, so score is +2. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is +3. *ii) Posture B*: The neck angle is 41.5˚±12.40˚ so score is +3. The trunk angle is 43.30˚±6.11˚, so score is +3. The legs are supported equally, so the score is +1. The final posture B is +4. The muscle score is +0 since no condition is matched and the force/load score is +3 since the load in hand is 11.35 kg and it was repeated. So, the final score of RULA is 7.

For person 2, i) Posture A: The upper arm average angle is 60.48˚±28.67˚. So, the score is +3, and the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle is 108.98˚±21.83˚, so the score is +2. From the observation, the wrist is neutral, so +1. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is +3. ii) Posture B: The neck angle is 8.67˚±5.86˚, so score is +1. The trunk angle is 16.55˚±6.46, so score is +2. The legs are supported equally, so the score is +1. The final posture B is +2. The muscle score is +0 since no condition matched and the force/load score is +3 since the load in hand is 11.58 kg and it was repeated. So, the final score of RULA is 6.

For person 3, i) Posture A: The upper arm average angle is 59.96˚±34.87˚, so the score is +3, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle of flexion is 83.79˚±22˚, so the score is +1, no adjustment. From the observation, the wrist is deviating with 15˚ and no adjustment, so score is +2. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 3. ii) Posture B: The neck score is +3, since assuming neck angle is more than 20 in flexion. The trunk angle is 43.30˚±6.11˚, so score is +3. Participant doesn't support on both legs, so +2. The final posture B is +4. The muscle score is +0 since none the conditions were present and the force/load score is +3 since the load in hand is 11.26 kg and it was repeated. So, the final score of RULA is 7.

For person 4, i) Posture A: The upper arm average angle is 69.76˚±36.73˚. so the score is +3, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle of flexion is 94.32˚±29.10˚, so the score is +1. From the observation, the wrist is deviating with 15˚, so score is +2. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 3. ii) Posture B: From observation, the neck angle is in extension, so score is +4. The trunk angle is within the range of 20˚-60˚, so score is +3. The legs are supported equally, so the score is +1. The final score of posture B is +6. The muscle score is +0 since no condition is present and the force/load score is +3 since the load in hand is 11.89 kg and it was repeated. So, the final score of RULA is 7.

For person 5, i) Posture A: The upper arm average angle is 40.6˚±28.01˚, so the score is +2, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +1. The lower arm angle of flexion is 98.97˚±15.58˚, so the score is +1. From the observation, the wrist is on neutral, score is +1. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is +2. ii) Posture B: The neck angle is within 10˚-20˚, so score is +2. The trunk angle is within 0-20˚, so score is +2. The legs are supported equally, so the score is +1. The final posture B is +4. The muscle score is +0 and the force/load score is +2 since the load in hand is 7.18 kg and it was repeated. So, the final score of RULA is 4.

For person 6, i) Posture A: The upper arm average angle is 57.89˚±20.05˚, therefore the score is +3, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle of flexion is 90.54˚±22.78˚, so the score is +1, no adjustment. From the observation, the wrist is deviating with 15˚ and no adjustment, so score is +2. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 3. ii) Posture B: The neck angle is more than 20˚, so score is +3. The trunk angle is 23.46˚±6.71˚, so score is +3. The legs are supported equally, so the score is

+1. The final posture B is +4. The muscle score is +0 and the force/load score is +2 since the load in hand is 8.13 kg and it was repeated. So, the final score of RULA is 7.

For person 7, i) Posture A: The upper arm average angle is 43.81˚±20.05˚. So, the score is +2, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +1. The lower arm angle of flexion is 103˚±17.1˚, so the score is +2. From the observation, the wrist is in 0˚, so score is +1. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 2. ii) Posture B: The neck angle is 14.1˚±6.06˚, so score is +2. The trunk angle is 21.1˚±11.74˚, so score is +3. The legs are not supported equally, so the score is +2. The final posture B is +5. The muscle score is +0 and the force/load score is +3 since the load in hand is 11.1 kg and it was repeated. So, the final score of RULA is 7.

For person 8, i) Posture A: The upper arm average angle is 56.9˚±25.5˚, so the score is +3, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle of flexion is 98.36˚±18.58˚, so the score is +1, no adjustment. From the observation, no deviation in wrist, so score is +1. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 2. ii) Posture B: The neck angle is 14.57˚±7.25˚, so score is +2. The trunk angle is 18.84˚±5.75˚, so score is +2. The legs are supported equally, so the score is +1. The final posture B is +4. The muscle score is +0 and the force/load score is +3 since the load in hand is 11.51 kg and it was repeated. So, the final score of RULA is 6.

For person 9, i) Posture A: The upper arm average angle is 52.35˚±27.06˚. so the score is +3, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle of flexion is 78.18˚±20.1˚, so the score is +1, no adjustment. From the observation, no deviation in wrist, so score is +1. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 2. ii) Posture B: The neck angle is in extension, so the score is +4. The trunk angle within the range of 20-60˚, so score is +3. The legs are supported equally, so the score is +1. The final posture B is +6. The muscle score is +0 and the force/load score is +3 since the load in hand is 11.76 kg and it was repeated. So, the final score of RULA is 7.

For person 10, i) Posture A: The upper arm average angle is 69.71˚±23.03˚. So, the score is +3, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle of flexion is 101.27˚±22.06˚, so the score is +1, no adjustment. From the observation, the wrist is deviating with 15˚ and no adjustment, so score is +2. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 3. ii) Posture B: The neck angle is 19.2˚±2.9˚, so score is +2. The trunk angle is 33˚±3.17˚, so score is +3. The legs are not supported equally, so the score is +2. The final posture B is +5. The muscle score is +0 and the force/load score is +3 since the load in hand is 11.63 kg and it was repeated. So, the final score of RULA is 7.

For person 11, i) Posture A: The upper arm average angle is 49.7˚±32.67˚, so, the score is +3, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +2. The lower arm angle of flexion is 84.85˚±14.27˚, so the score is +1, no adjustment. From the observation, the wrist is in neutral, so score is +1. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 2. ii) Posture B: The neck angle is 30.38˚±9.51˚ so score is +3. The trunk angle is 28.72˚±5.23˚, so score is +3. The leg is not supported equally, so the score is +2. The final posture B is +4. The muscle score is +1 since the action is done 4 times in a minute and the force/load score is +3 since the load in hand is 11.83 kg and it was repeated. So, the final score of RULA is 7.

For person 12, i) Posture A: The upper arm average angle is 41.67˚±33.61˚, so, the score is +2, but by adjustment, the person is leaning so -1. Therefore, the total score of the upper arm is +1. The lower arm angle of flexion is 96.13˚±36.74˚, so the score is +1, no adjustment. From the observation, the wrist is not deviating, so score is +1. For the wrist twist the score is +1 since it twisted in mid-range. so, the final score of posture A is 2. ii) Posture B: The neck angle is 29.5˚±16.03˚, so score is +3. The trunk angle is 17˚±9.67˚, so score is +2. The leg is not equally supported equally, so the score is +2. The final posture B is +4. The muscle score is +1 since the action is done 4times in a minute and the force/load score is +2 since the load in hand is 7.97 kg and it was repeated. So, the final score of RULA is 6.

Table 5-2 RULA assessment score of every participant

Person	Arm & Wrist Analysis								Neck, Trunk & Leg Analysis							Final Score
	Upper Arm Score	Lower Arm Score	Wrist Score	Wrist Twist Score	Posture Score of Table A	Muscle Use Score	Force/Load Score	Wrist & Arm Score	Neck Score	Trunk Score	Leg Score	Posture Score of Table B	Muscle Use Score	Force/Load Score	Neck, Trunk & Leg Score	
1	2	1	2	1	3	0	3	6	3	3	1	4	0	3	7	7
2	2	2	1	1	3	0	3	6	1	2	1	2	0	3	5	6
3	2	1	2	1	3	0	3	6	3	3	2	5	0	3	8	7
4	2	2	2	1	3	0	3	6	4	3	1	6	0	3	9	7
5	1	1	1	1	1	0	2	3	2	2	1	2	0	2	4	4
6	2	1	2	1	3	0	2	5	3	3	1	4	0	2	6	7
7	1	2	1	1	2	0	3	5	2	3	2	5	0	3	8	7
8	2	1	1	1	2	0	3	5	2	2	1	1	0	3	4	5
9	2	1	1	1	2	0	3	5	4	3	1	6	0	3	9	7
10	2	1	2	1	3	0	3	6	2	3	2	5	0	3	8	5
11	2	1	1	1	2	0	3	5	3	3	2	5	0	3	8	7
12	1	1	1	1	1	0	2	3	3	2	2	4	0	2	6	5

5.2.2 Result of REBA assessment

REBA assessment was done under the observation of the videos and verbal information regarding their action so we can understand the depth of the pattern of action and analyse it as the way we want to. The observation was done on the only one side in the sagittal plane. The scoring process was an additional process and it is little bit different from RULA assessment test. The adjustment was done as per use of the standard chart of REBA process. REBA assessment also divided in Posture A and Posture B. Posture A is consist of neck, trunk, leg score whereas, posture B is consisting of upper arm, lower arm, wrist position. In REBA process, for everyone the adjustment score of the upper arm position is -1 since the person is leaning and coupling score is 0, since coupling score is used for the gripping process. And here, the griping on the rope is pretty much fitted and welled powerful. For activity score +1 since because of the action body swings or it has unstable base. So, the evaluation is given –

For person 1, i) Posture A: The neck angles are 41.5˚±12.40˚ so score is +2. Trunk angle is 43.30˚±6.11˚, so score is +3. The leg score is +1 for equally supported and no adjustment. So, the score of posture A is 4. ii)Posture B: The upper arm angle is 67.59˚±28.01˚. So, the score is +3, but by adjustment, the person is leaning so -1. So, the total score +2. The lower arm is in 90.54˚±22.78˚, so the score is +1. The angle deviation of wrist is within 15˚, so score is +1, adjusting the wrist twist +1, so total wrist score is +2. So, the posture B score is 2. The Force/Load score is +2 because the load in hand is 11.35 kg. the coupling score is 0. The score of table c is 6. And the activity score is +1. So, the final score of REBA assessment is 7.

For person 2, i) Posture A: The neck angles is 8.67±5.86 so score is +1. The trunk angle is 16.55˚±6.46˚, so score is +2. The leg score is +1. So, the score of posture A is 2. ii)Posture B: The upper arm angle is 60.48˚±28.67˚. So, the score is +3, but by adjustment, the person is leaning so -1. So, the total score +2. The lower arm is in 108.98.˚±.21.83˚, so the score is +2. No angle of deviation of wrist but twisting in mid-range, so the total score is +1. So, the posture B score is 2. The Force/Load score is +2 because the load in hand is 11.85 kg. the coupling score is 0. The score of table c is 4. And the activity score is +1. So, the final score of REBA assessment is 5.

For person 3, i) Posture A: The neck angle is more than 20˚ in flexion, so score is +2. Trunk angle is 43.30˚±6.11˚, so score is +3. The leg score is +2 for not equally supported So, the score of posture A is 5. ii)Posture B: The upper arm angle is 59.96˚±34.87˚. so the score is +3, but by adjustment, the person is leaning so -1. So, the total score +2. The lower arm is in 83.97˚±22˚, so the score is +1. The angle deviation of wrist is within 15˚ (+1) and twisting in mid-range (+1) so total score +2. So, the posture B score is 2. The Force/Load score is +2 because the load in hand is 11.35 kg. the coupling score is 0. The score of table c is 7. And the activity score is +1. So, the final score of REBA assessment is 8.

For person 4, i) Posture A: The neck angle is in extension so score is +2. Trunk angle is 4within 20-60˚, so score is +3. The leg score is +1 for equally supported and no adjustment is needed, so the total score is +1. So, the score of posture A is 4. ii)Posture B: The upper arm angle is 69.76˚±36.73˚. So, the score is +3, but by adjustment, the person is leaning so -1. So the total score +2. The lower arm is in 94.32˚±29.10˚, so the score is +1. The angle deviation of wrist is within 15˚ so score +1 and for wrist twist in midline +1, so total score is +2. So the posture B score is 2. The Force/Load score is +2 because the load in hand is 11.89 kg. the coupling score is 0. The score of table c is 6. And the activity score is +1. So, the final score of REBA assessment is 7.

For person 5, i) Posture A: The neck angle is within 0-20˚ so score is +1. Trunk angle is within 0-20˚, so score is +2. The leg score is +1 for equally supported. So, the score of posture A is 2. ii)Posture B: The upper arm angle is 40.6˚±28.01˚. So, the score is +2, but by adjustment, the person is leaning so -1. So, the total score +1. The lower arm is in 98.97˚±15.58˚, so the score is +1. No score for angle deviation of wrist but +1 for twisting in midline, total score in wrist +1. So, the posture B score is 1. The Force/Load score is +1 because the load in hand is 7.18 kg. the coupling score is 0. The score of table c is 2. And the activity score is +1. So, the final score of REBA assessment is 3.

For person 6, i) Posture A: The neck angle is more than 20˚ so score is +2. Trunk angle is 23.46˚±6.71˚, so score is +3. The leg score is +1 for equally supported. So, the score of posture A is 4. ii)Posture B: The upper arm angle is 57.89˚±20.05˚. So, the score is +3, but by adjustment, the person is leaning so -1. So, the total score +2. The lower arm is in 90.54˚±22.78˚, so the score is +1. The angle deviation of wrist is within 15˚and twisted, +2. So, the posture B score is 2. The Force/Load score is +1 because the load in hand is

8.13 kg. the coupling score is 0. The score of table c is 4. And the activity score is +1. So, the final score of REBA assessment is 5.

For person 7, i) Posture A: The neck angles is 14.1˚±6.06˚ so score is +1. Trunk angle is 21.1˚±11.74˚, so score is +3. The legs score are +2 for not equally supported. So, the score of posture A is 4. ii)Posture B: The upper arm angle is 43.81˚±20.05˚. So, the score is +2, but by adjustment, the person is leaning so -1. So, the total score +1. The lower arm is in 103˚±17.1˚, so the score is +2. The angle deviation of wrist is 0˚and twisted +1. So, the posture B score is 1. The Force/Load score is +2 because the load in hand is 11.1 kg. the coupling score is 0. The score of table c is 6. And the activity score is +1. So, the final score of REBA assessment is 7.

For person 8, i) Posture A: The neck angle is 14.57˚±7.25˚ so score is +1. Trunk angle is 18.84˚±5.75˚, so score is +2. The leg score is +1 for equally supported. So, the score of posture A is 2. ii)Posture B: The upper arm angle is 56.9˚±25.5˚. So, the score is +3, but by adjustment, the person is leaning so -1. So, the total score +2. The lower arm is in 98.36˚±18.58˚, so the score is +1. The wrist only twisting, so +1. So, the posture B score is 1. The Force/Load score is +2 because the load in hand is 11.51 kg. the coupling score is 0. The score of table c is 3. And the activity score is +1. So, the final score of REBA assessment is 4.

For person 9, i) Posture A: The neck angle is in extension so score is +2. Trunk angle is in between 20-60˚, so score is +3. The leg score is +1for equally supported. So, the score of posture A is 4. ii)Posture B: The upper arm angle is 52.35˚±27.06˚. So, the score is +3, but by adjustment, the person is leaning so -1. So, the total score +2. The lower arm is in 78.18˚±20.1˚, so the score is +1. No deviation of wrist but twisted so +1. So, the posture B score is 1. The Force/Load score is +2 because the load in hand is 11.76 kg. the coupling score is 0. The score of table c is 6. And the activity score is +1. So, the final score of REBA assessment is 7.

For person 10, i) Posture A: The neck angle is 19.2˚±2.9˚ so score is +1. Trunk angle is 33˚±3.17˚, so score is +3. The leg score is +2 for not equally supported, so the total score is +2. So, the score of posture A is 4. ii)Posture B: The upper arm angle is 67.59˚±28.01˚. So the score is +3, but by adjustment, the person is leaning so -1. So, the total score +2. The lower arm is in 101.27˚±22.06˚, so the score is +2. The angle deviation of wrist is within 15˚ and also twisted, so score is 2. So, the posture B score is 3. The Force/Load score is +2 because the load in hand is 11.63 kg. the coupling score is 0. The score of table c is 6. And the activity score is +1. So, the final score of REBA assessment is 7.

For person 11, i) Posture A: The neck angle is 30.38˚±9.51˚ so score is +2. Trunk angle is 28.72˚±5.23˚, so score is +3. The leg score is +2 for not supported equally. So, the score of posture A is 5. ii)Posture B: The upper arm angle is 49.7˚±32.67˚, so the score is +3, but by adjustment, the person is leaning so -1. So, the total score +2. The lower arm is in 84.85˚±14.27˚, so the score is +1. No angle of deviation in wrist but twisted, so, +1. So, the posture B score is 1. The Force/Load score is +2 because the load in hand is 11.83 kg. the coupling score is 0. The score of table c is 7. And the activity score is +1. So, the final score of REBA assessment is 8.

For person 12, i) Posture A: The neck angle is 29.5˚±16.03˚ so score is +2. Trunk angle is 17˚±9.67˚, so score is +2. The leg score is +2 since not equally supported. So, the score of posture A is 4. ii)Posture B: The upper arm angle is 41.67˚±33.61˚, so the score is +2, but by adjustment, the person is leaning so -1. So, the total score +1. The lower arm is in 96.13˚±36.74˚, so the score is +1. The angle deviation of wrist is 0˚ but it is twisting, +1. So, the posture B score is 1. The Force/Load score is +2 because the load in hand is 7.97 kg. the coupling score is 0. The score of table c is 4. And the activity score is +1. So, the final score of REBA assessment is 5.

Table 5-3 REBA assessment score of every participant

Person	Neck, Trunk & Leg Analysis						Arm & Wrist Analysis						Table C Score	Activity Score	Final REBA Score
	Neck Score	Trunk Score	Leg Score	Posture score of Table A	Force/Load Score	Score A	Upper Arm	Lower Arm Score	Wrist	Posture Score of Table B	Coupling Score	Score B			
1	2	3	1	4	2	6	2	1	2	2	0	2	6	1	7
2	1	2	1	2	2	4	2	2	1	2	0	2	4	1	5
3	2	3	2	5	2	7	2	1	2	2	0	2	7	1	8
4	2	3	1	4	2	6	2	1	2	2	0	2	6	1	7
5	1	2	1	2	1	3	1	1	1	1	0	1	2	1	3
6	2	3	1	4	1	5	2	1	2	2	0	2	4	1	5
7	1	3	2	4	2	6	1	2	1	1	0	1	6	1	7
8	1	2	1	2	2	4	2	1	1	1	0	1	3	1	4
9	2	3	1	4	2	6	2	1	1	1	0	1	6	1	7
10	1	3	2	4	2	6	2	2	2	3	0	3	6	1	7
11	2	3	2	5	2	7	2	1	1	1	0	1	7	1	8
12	2	2	2	4	1	5	1	1	1	1	0	1	4	1	5

5.2.3 ART Assessment result:

ART assessment works differently for every individual. Since, it is mainly for the manual handling process, therefore, the score that has been get are much more contributed to understand the upper limb disorder. Here, three colour is used, green for no risk, amber for medium risk, red for high risk. The assessment is only done on the one of the sides of the video involve. The assessment is done on 4 steps. Step one So the result of the participants are given –

For the person 1, i) Frequency/repetition: Arm movement (A_1) is seen as frequent or regular movement so the colour is Amber and score is 3. Arm repetition (A_2) is in the similar manner repeating 11 to 20 times per minute, so score is and colour is 3 and amber. ii) Force (B): the force is moderate force and acts for 80% of the time, so score is 8 and colour is red. iii) Awkward posture: For head and neck posture (C_1), the neck is bent more than the half of the time, so score 2 and colour red. For back posture(C_2), bend forward more than the half of the time, so score 2, colour red. For arm posture(C_3), elbow raised way from body for half of the time, so colour amber and score 2. For, wrist posture (C_4), bent and deviated for the whole time, so colour red ad score 2. For gripping (C_5), score zero, colour green since it is a power grip. iv) Additional factors: The breaks (D_1) are after every 1hour to 2 hours of continue work, so score 2 and colour amber. For work pace (D_2), sometimes it is difficult to keep up, so score 1 and amber. For others factor (D_3), score 2 and red since more than two factor presents (the work cause discomfort in hands and fingers; the task needs fine precise movement of the body; the task causes tension on back). Duration(D_4), of the task is at least 3hours. The total task score is 28 and the exposure score is 21 which is medium level.

For the person 2, using the same interpretation as person 1 we get, i) Frequency/repetition: A_1 is 3. A_2 is 3 and amber. ii) Force B is 8 and colour is red. iii) Awkward posture: C_1, the neck is almost neutral, so score 0 and colour green. C_2, back posture is 1 and amber. For C_3, colour is amber and score 2. For, wrist posture (C_4), green and score is zero. For gripping (C_5), score zero, colour green since it is a power grip. iv) Additional factors: D_1 is score 2 and colour amber. For work pace (D_2), sometimes it is difficult to keep up, so score 1 and amber. For D_3, score 1 and red since one factor presents same as person 1. D_4, of the task is at least 4 to 8 hours. The total task score is 20 and the exposure score is 20 which is medium level of risk.

For the person 3, i) A_1 and A_2 is 3 and amber. ii) Force B is 8 and red. iii) Awkward posture: C_1 and C_2 is 2 and red colour. For C_3, colour is red and score is 4. C_4, is red and score is 2. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 2 and amber colour. D_2, scores 2 and red. For D_3, score 2 and red since more than two factor presents same as person 1. D_4, of the task is at least 2 to 4 hours. The total task score is 30 and the exposure score is 22.5 which is high level risk.

For the person 4, i) $A_1$and A_2 is 3 and amber. ii) Force B is 8 and red. iii) Awkward posture: C_1 and C_2 is 2 and red colour. For C_3, colour is red and score is 4. C_4, is red and score is 2. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 4 and amber colour. D_2, scores 1 and red. For D_3, score 2 and red since two factor presents. D_4, of the task is at least 2 to 4 hours. The total task score is 28 and the exposure score is 21 which is medium level of risk.

For the person 5, i) A_1 and A_2 is 3 and amber. ii) Force B is 4 and amber. iii) Awkward posture: C_1 is 1, and C_2 is 0. For C_3, colour is red and score is 2. C_4, is red and score is 0. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 4 and amber colour. D_2, scores 1 and amber. For D_3, score 1 and amber since one factor presents. D_4, of the task is at least 2 to 4 hours. The total task score is 19 and the exposure score is 14.25 which is medium level.

For the person 6, i) A_1 and A_2 is 3 and amber. ii) Force B is 4 and amber. iii) Awkward posture: C_1 and C_2 is 2 and red colour. For C_3, colour is amber and score is 2. C_4, is red and score is 2. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 4 and amber colour. D_2, scores 1 and amber. For D_3, score 2 and red since more than two factor presents. D_4, of the task is at least 2 to 4 hours. The total task score is 25 and the exposure score is 18.75 which is medium level.

For the person 7, i) A_1 and A_2 is 3 and amber. ii) Force B is 8 and red. iii) Awkward posture: C_1 and C_2 is 2 and red colour. For C_3, colour is amber and score is 2. C_4, is green and score is 0. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 2 and amber colour. D_2, scores 2 and red. For D_3, score 2 and red since more than two factor presents. D_4, of the task is at least 2 to 4 hours. The total task score is 27 and the exposure score is 20.25 which is medium level.

For the person 8, i) A_1 and A_2 is 3 and amber. ii) Force B is 8 and red. iii) Awkward posture: C_1 is 0 and green colour, C_2 is 2 and red colour. For C_3, colour is amber and score is 2. C_4 and C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 4 and amber colour. D_2, scores 1 and amber colour. For D_3, score 2 and red. D_4, of the task is at least 2 to 4 hours. The total task score is 25 and the exposure score is 18.75 which is medium level risk.

For the person 9, i) A_1 and A_2 is 3 and amber. ii) Force B is 8 and red. iii) Awkward posture: C_1 and C_2 is 2 and red colour. For C_3, colour is amber and score is 2. C_4, is zero and green. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 4 and amber colour. D_2, scores 2 and red. For D_3, score 2 and red since more than two factor presents same as person 1. D_4, is of the task is at least 2 to 4 hours. The total task score is 28 and the exposure score is 21 which interprets risk level as medium.

For the person 10, i) A_1 and A_2 is 3 and amber. ii) Force B is 8 and red. iii) Awkward posture: C_1 and C_2 is 2 and red colour. For C_3, colour is green and score is 2. C_4, is red and score is 2. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 2 and amber colour. D_2, scores 2 and red. For D_3, score 1 and red since one factor presents. D_4, of the task is at least 1 to 2 hours. The total task score is 27 and the exposure score is 13.5 interprets risk as medium level.

For the person 11, i) A_1 and A_2 is 3 and amber. ii) Force B is 8 and red. iii) Awkward posture: C_1 and C_2 is 2 and red colour. For C_3, colour is green and score is 2. C_4, is green and score is 0. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 2 and amber colour. D_2, scores 2 and red. For D_3, score 1 and red one factor presents. D_4, of the task is at least 1 to 2 hours. The total task score is 25 and the exposure score is 12.5 which is medium level.

For the person 12, i) A_1 and A_2 is 3 and amber. ii) Force B is 4 and amber. iii) Awkward posture: C_1 is 1 and colour is amber. C_2 is 0 and green colour. For C_3, colour is amber and score is 2. C_4, is green and score is 0. For gripping C_5, score is zero and colour is green. iv) Additional factors: D_1 scores 2 and amber colour. D_2, scores 2 and red. For D_3, score 2 and red since more than two factor presents. D_4, of the task is at least 1 to 2 hours. The total task score is 19 and the exposure score is 9.5 which interprets the risk as low level.

Table 5-4 ART score for every participant

Person	1	2	3	4	5	6	7	8	9	10	11	12
Risk factors	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score
A1 Arm movement	3	3	3	3	3	3	3	3	3	3	3	3
A2 Repetition	3	3	3	3	3	3	3	3	3	3	3	3
B Force	8	8	8	8	4	4	8	8	8	8	8	4
C1 Head/Neck posture	2	0	2	1	1	2	2	0	2	2	2	1
C2 Back posture	2	0	2	2	0	2	2	2	2	2	2	0
C3 Arm Posture	2	2	4	2	2	2	2	2	2	2	2	2
C4 Wrist Posture	2	0	2	2	0	2	0	0	0	2	0	0
C5 Hand/finger grip	0	0	0	0	0	0	0	0	0	0	0	0
D1 Breaks	4	2	2	4	4	4	4	4	4	2	2	2
D2 Work Pace	0	1	2	1	1	1	1	1	2	2	2	2
Other Factors	2	1	2	2	1	2	2	2	2	1	1	2
Task Score	28	20	30	28	19	25	27	25	28	27	25	19
x D4 duration	0.75	1	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.5	0.5	0.5
Exposure Score	21	20	22.5	21	14.25	18.75	20.25	18.75	21	13.5	12.5	9.5
D5 Psychological factors												

5.3 Human Motion Analysis Method

- Stick diagram or stick figure representation.
- Joint Linear Displacement and Angular Displacement.

5.3.1 Stick diagram or stick model representation

The stick diagram or stick figures represent the movement pattern for the human body. Here, the stick diagram shows the projected position of human body. The diagram is only for pulling the body. “+----" represents the start of pulling and “x----" represents the end of pulling of one cycle. The movement given here is for one half cycle another half is releasing.

For person 1, here, the wrist joint shows minimal displacement at first and then higher displacement and then at the end again the relative position is minimum Same it goes for Elbow joint too, minimal-higher-minimal displacement. The tracing line, if possible, in shoulder joint will shows that the shoulder gives quite a circular (inside to outside) movement. The hip joint shows, the hip moves behind and make a little bit of inclination. Same with knee joint, it moves behind. The ankle joint doesn’t seem to be change.

For person 2, here, wrist joint and elbow joint both displaced with minimal changes at first then it to varies highly and at the end of the projection, it can see that the gap still present is small. The shoulder moves backward with small initial to bigger and before the end it took small displacement. The hip joint is seeming to be moves with small distance. Then knee joint also changes its position with small variation. Ankle joint seems to be fixed or movement is negligible.

For person 3, the wrist joint seems to be moving with same displacement. Elbow joint at first it moves with having high displacement but at the end it has small displacement. The shoulder joint has small displacement until the end. Hip and knee joint moves behind with small variation. Ankle joint shows low displacement

For person 4, for the half cycle, the wrist and elbow joint shows small amount of variation at the first and at the last. During the meantime, the displacement is higher. Shoulder Joint shows, at first it changes in equal displacement till it moves backward. Hip and knee joint moves backward with small inclination. Ankle joint nearly remain constant

For person 5, wrist and elbow joint changes its displacement from higher to lower. The shoulder joint can have eclipse line to be form in imagination which shows the shoulder movement doesn't change much from its position. Hip joint and knee joint changed is position and moves behind, shows incline imaginary line. Ankle joint doesn't change.

For person 6, wrist joint moves down even though the elbow joint moves in a trajectory path. The start and end of shoulder joint lies in such closure, it can say the shoulder joint doesn't move much. Hip joint moves backward having inclination. Knee joint doesn't show much difference but Ankle joint moves from behind to forward.

For person 7, the wrist joint and elbow joint shows minimal displacement throughout the cycle then it shows high displacement. Wrist and elbow segment come towards the body. Shoulder joint moves from forward to behind at first and then again moves to forward but shows low displacement as in the first. The hip joint shows a hip displacement with similar effects as in shoulder. Knee joint seems to have a rotational trajectory path with minimal-higher-minimal movements. Ankle joint seems to have movement in backward direction too.

For person 8, the elbow and wrist joint have small to large movement. while very low shoulder movement. The hip joint holds the same throughout the movement. Knee joint changes very small displacement. Ankle joint seems to be staying in the same position.

For person 9, the elbow and wrist joint moves from higher to lower with small-large-small movement pattern. Shoulder swings forward first then came back in a trajectory path. Hip joint moves from forward to backward which shows a bending between the segment. Knee joint shows movement with small amount of displacement along with Ankle joint.

For person 10, the wrist and elbow joint shows equal displacement at first but then in changes to high and make it look like an inclination line for wrist joint, and for elbow joint it shows a swing movement. Shoulder joint doesn't make rotation. hip joint starts to change in flexion and doesn't show very much movement. Knee joint changes to nearly a straight line with ankle from flexion. And the ankle joint doesn't seem to be move.

For person 11, the wrist joint moves with equal subinterval but shows instability whereas the elbow joint shows a perfect swing of movement. The shoulder joints show a trajectory path that can say that the shoulder joint will be move back to the same initial position. Hip joint moves back and it swings keeping position nearly same. Knee segment becomes straight line keeping ankle joint in the same position

For person 12, the wrist joint moves in the equal subinterval from start to end. The elbow joint also moves with equal subinterval with swing. Same goes with shoulder joint, it swings in trajectory path and can be moves to initial position if possible. Hip joint moves backward from its initial position while swinging. Knee joint swings and tried to make a straight-line then again swings back. Ankle joint doesn't seem to moves.

5.3.2 Joint Linear Displacement and Angular Displacement

5.3.2.1 Linear Displacement

1) Horizontal Position of Joints

From the graphical representation of horizontal position for person 1 has been founded that her wrist joint has maximum displacement of 38.28 cm and minimum displacement of -2.98 cm. The decreasing in horizontal position shows the pulling towards body, in the meantime the shoulder joint also decreased, and because of the swinging of hip and knee, it tried to remain as close as can be from its initial position. But the ankle joint doesn't change so much.

The graphical representation of person 2 shows, at first the wrist joint position increase because she extends the hand first, therefore along with the wrist joint, position of elbow joint, shoulder joint, hip joint, knee joint also increases. After 1000ms, the position started to decrease because at that time, she starts to pull, so all the joint position starts to move behind even the hip, but to have a balance in ankle to knee joint, knee joint doesn't move behind a lot.

It tried to stopped for a bit and the ankle joint moves much less that it can be neglected.

For person 3, the all the joints displacement went correct but there's some confusion in hip joint because the hip joint moves a lot in this case. The displacement in hip joint doesn't show the swinging against wrist, elbow, shoulder joint.

For person 4, the curves show a perfect synchronization of all the joints. Without a lot of displacement of shoulder joint and knee joint and ankle joint, the wrist joint, elbow joint, hip joint matches the same way position change. It causes less stress on hip.

For person 5, the curve shows that the hip and knee joint cause a high swing during pulling but the shoulder joint move behind to the same position as much it was forwarded. The wrist and elbow joint goes simultaneously, there's a sharp or rapid increase in wrist joint which is not present for the elbow joint.

For person 6, the position of wrist joint and elbow joint changes dramatically. The shoulder position of shoulder joint increased very slowly. The hip joint swings so smoothly as given in curve. Knee and ankle joint remain closer to unchanged.

For person 7, the wrist and elbow joint climb up and fall very drastically for the two cycles. But the shoulder joint first shows a perfect synchronization but then for the second time, the position decreases. Same goes for hip joint and knee joint. For first cycle knee and hip joint changes position in higher but for second cycle, the it decreases their position of moving.

For person 8, here, the data shows that the wrist joint, elbow joint, shoulder joint moves in synchronization having hip joint displacement nearly unchanged. Knee joint moves in smaller displacement and the ankle joint remain unchanged.

For person 9, the wrist and elbow joint moves in perfect way with synchronization. While, shoulder joint shows small unstable movement. Hip joint moves in smaller displacement with instability. The ankle joints approximately remain unchanged.

For person 10, in the both cycle the data shows a perfect synchronization of all the joint. When wrist, elbow, shoulder joint flexion, the hip and knee joint displaced very smoothly. The ankle joint remains unchanged very closely.

For person 11, Here, shoulder joint, hip joint, knee joint, ankle joint doesn’t show deflection in displacement. But here, wrist joint moves in high records with lower movement in elbow joint.

For person 12, here, the again wrist joint, elbow joint, shoulder joint moves frequently with same extension interval in joint. While doing so, hip joint moves with less displacement. Knee joint tries to have equal displacement in swing. The ankle joint remains unchanged.

2) Vertical Position of Joints

The vertical position for participants seems to be in same way as horizontal displacement of the joints. Here, the displacement is basically difference in the position of initial-final in the same interval time. So, maximum and minimum value for the most movable joints are given –

For person 1, the vertical position of wrist joint goes up to 7.47 cm, elbow joint goes nearly -5.99 cm. Shoulder joint has displacement maximum at -0.15 cm. hip joint, knee joint, ankle joint seems to remain constant nearly or the displacement is very small.

For person 2, hip joint, knee joint and ankle joint line deflected in very small unit from its initial position having average displacement of -52.57 cm, -87.08 cm, -122.69 cm. the shoulder joint has approx. same deflection with average displacement -4.01 cm. the wrist and elbow joint moves in the vertical direction having maximum displacement of 6 cm and -119.51 cm.

For person 3, the wrist joint, elbow joint, shoulder joint moves in the vertical direction with a lot of rapid changes the with average displacement of -23.61cm, -33.75cm, -15.21cm.

For person 4, the wrist, elbow, shoulder joint moves with rapid changes with maximum displacement of 22.73cm, 4.71cm, 0.04 cm and minimum -39.95cm, -49.24cm, -22.2cm.

For person 5, the maximum displacement in vertical direction of wrist joint, elbow joint, shoulder joint can have 7.54cm, -7.06cm, 4.031cm and the minimum displacement of hip, knee joint can be -54.11cm, -85.5394cm.

For person 6, other than wrist and elbow joint, all joint seems to move quite low displacement. So, wrist and elbow have maximum displacement of 9.96 cm and -5.02cm.

For person 7, the wrist moves a lot keeping elbow nearly low changes having maximum displacement -20.18cm.

For person 8, the interval of displacement in wrist and elbow seems to be having same range. The average displacement of wrist and elbow joint is -5.27 cm and -16.56cm.

For person 9, wrist and elbow joint moves same keeping the interval nearly, the maximum displacement of wrist -2.83cm and elbow joint is -13.48 cm.

For person 10, the maximum displacement of wrist is 13.39cm and elbow is -0.78653. the minimum displacement of wrist is -37.71 and elbow is -37.38 cm. Other joints move nearly constant other than hip.

For person 11, except wrist and elbow joint, other joints don’t change much. So, maximum and min the joint can displace is 1.93 cm and -6.07cm.

For person 12, the displacement is same as others participants. Other than wrist and elbow, no abnormal displacement.

3) Horizontal Velocity of joints

Here, the x axis represents the time and y axis represents the horizontal velocity of the joints. As the joints moves in a trajectory way, it has both velocity direction. The wrist joint and elbow joint has the most variation. Here, the horizontal velocities are stated –

For person 1, the wrist joint and elbow joint has the most rapid change in velocity other than any joints. The maximum velocity wrist can have 1.55m/s and elbow have 1.36m/s.

For person 2, all the joints are kept changing with variation. Average velocity for the joints is -0.02 m/s, for elbow -0.03 m/s & shoulder, hip, knee, ankle joint, it is 0.01m/s.

For person 3, the wrist and elbow joint have the maximum velocity with 2.39 m/s and 2.43 m/s and the least velocity has ankle, since it nearly has no displacement.

For person 4, the maximum and minimum velocity wrist, elbow, shoulder joint can have is 0.94m/s, 1.26m/s, 0.79m/s and -0.89m/s, -1.07m/s, -0.62m/s. Hip is trying to be in static mode but the average velocity for knee is 0.02 m/s.

For person 5, all the joints move with quiet same variation. The average velocity for hip seems to be neutral, but ankle joint moves with nearly constant velocity. The average horizontal velocity for wrist, elbow, shoulder, knee joint is -0.09m/s, -0.11 m/s, -0.04m/s, -0.01m/s.

For person 6, other than wrist and elbow joint, all the joints range its horizontal velocity within the range of -0.2 to 0.2 m/s. the maximum to minimum velocity for wrist and elbow joint is 0.30m/s to -0.52 m/s and 0.60m/s to -0.87m/s.

For person 7, the maximum velocity for wrist and hip joint is 0.72m/s and elbow is 1.2m/s. The shoulder, knee has maximum velocity of 0.49 m/s and 0.33 m/s.

For person 8, other than hip, knee, ankle joint, all have rapid variation. The maximum velocity wrist and elbow joint can have 1.56 m/s and 1.71m/s.

For person 9, other than wrist and elbow joint all are nearly constant in velocity. The maximum velocity wrist and elbow joint have 1.9 m/s and 1.18m/s.

For person 10, other than wrist and elbow joint all are nearly constant in velocity. The maximum velocity wrist and elbow joint have 1.36 m/s and 1.75 m/s. The minimum velocity has -1.65m/s and -1.69m/s.

For person 11, the wrist and elbow joint has the maximum and minimum velocity of 0.23m/s to -0.53 m/s and 0.25 m/s to -0.5m/s. All other joints have very low variation.

For person 12, all the joints carry different velocities leaving ankle joint. The maximum velocity for wrist is 1.16 m/s, elbow 1.37m/s, shoulder 0.65m/s, hip 0.44m/s and knee 0.34m/s.

4) Vertical Velocity of Joints

Here, the x axis represents the time in milliseconds and the y axis represents the vertical velocity of the joints.

For person 1, the wrist and elbow joint moves in nearly sinusoidal curve. Wrist joint moves with maximum 1.69 m/s and minimum -1.22 m/s velocity. The elbow joint moves with maximum and minimum velocity of 0.96 and -0.94 m/s. The shoulder joint moves with maximum velocity 0.35 m/s and minimum velocity -0.52 m/s. The hip, knee, ankle joint moves with average velocity of -0.01 m/s, 0 m/s and 0.01 m/s.

For person 2, the wrist and elbow joint moves in nearly same. Wrist joint moves with maximum 1.44 m/s velocity. The elbow joint moves with minimum -1.16 m/s. The shoulder joint moves with maximum velocity 0.21 m/s and minimum velocity -0.40 m/s. The hip, knee, ankle joint moves with average velocity of -0.02 m/s.

For person 3, the wrist joint moves with maximum 2.84 and minimum -1.31 m/s velocity. The elbow joint moves with maximum and minimum velocity of 1.81 and -1.69 m/s. The shoulder joint moves with maximum velocity 0.42 m/s and minimum velocity -0.42 m/s. The hip, knee, ankle joint moves with average velocity of -0.03 m/s, -0.01m/s, -0.02m/s.

For person 4, the wrist, shoulder, ankle joint moves with average velocity of -0.01m/s. the maximum velocity knee has 0.05 m/s. Maximum and minimum velocity of elbow 0.91 and -1.07 m/s.

For person 5, the wrist joint moves with maximum 1.4 m/s and minimum -1.11 m/s velocity. The elbow joint moves with maximum and minimum velocity of 1.15 m/s and -1.29 m/s. The shoulder and hip joint moves with average velocity of -0.01m/s. The knee and ankle joint moves nearly with 0.01 m/s.

For person 6, the wrist joint moves with maximum 1.57 and minimum -0.67 m/s velocity. The elbow joint moves with maximum and minimum velocity 1.05 m/s and -0.63 m/s. The shoulder moves with average velocity of 0.01 m/s. The hip, knee and ankle joint moves with average velocity of -0.01 m/s.

For person 7, shoulder, knee and ankle joint moves with low variation, nearly constant. The wrist and elbow joint has maximum velocity of 1.48m/s and 0.57m/s.

For person 8, the ankle joint doesn't move a lot, therefore it moves with average velocity of 0.01m/s. The wrist joint moves with highest velocity of 1.11 m/s in the vertical direction. The shoulder joint has highest velocity of 0.25 m/s. The elbow joint, knee moves with 0.03 m/s, 0.02 m/s and hip moves with 0.01 m/s in average.

For person 9, wrist joint moves with maximum 1.90 and minimum -0.68 m/s velocity. The elbow joint moves with maximum and minimum velocity of 1.18 and -0.61 m/s. The shoulder, hip, knee and ankle joint moves without large variation.

For person 10, the wrist, elbow, shoulder joint has much deflection in vertical velocity. The wrist joint has highest and lowest value as 2.08 m/s and -1.61 m/s. The elbow grows rapidly as wrist joint and touches to higher value of 1.32 m/s and the shoulder joint deflected at maximum 0.31 m/s to -0.36 m/s. The hip, knee and angle joint moves with not much deflection but nearly steady.

For person 11, the shoulder joint, hip joint, knee joint extended and flexed and becomes neutral in average. The highest and lowest velocity of the wrist joint and elbow joint is 0.54 m/s, -0.20 m/s and 0.26 m/s, -0.19 m/s. the Ankle is said to be in a constant stage throughout the graph.

For person 12, the wrist joint and elbow joint changes its velocity very drastically having maximum velocity 1.5 m/s and 0.55 m/s in the y direction. The shoulder joint, hip joint, knee joint also moves drastically but lower than wrist joint and elbow joint. The ankle joint seems to be in a less deviation with average velocity -0.02 m/s in the y direction.

5) Total distance of joints

   Total distance is basically the resultant value of horizontal and vertical displacement. So, it is then can be said that the total distance will be higher for the wrist joint of every participant and lower will be for ankle joint given in graphical representation.

6) Speed of the joints

   Speed of the joints is the resultant value at what rate the joint travels a distance. So, we saw that the total distance travel by wrist joint is maximum and the total distance travel by ankle joint is minimum. Therefore, it is seen that the speed of the wrist joint is maximum and speed of the ankle joint is minimum.

5.3.2.2 Angular Displacement

The horizontal axis represents the time in milliseconds and the vertical axis shows the inside angles between joints in degrees. So, from the angle-time diagram we get the angular displacement during while moving or working.

For person 1, it shows that the elbow angle is higher when the hand is in extension and lower the angles when elbow is towards body or in flexion. Same goes for shoulder angle too. But it has seen that shoulder angle is much lower, it mostly because of the flexion in shoulder joint. The hip angle shows high value when it swings away from the optical axis of the camera and gets lower when swings toward the optical axis of the camera. Knee angle goes close to 180˚ which means at that time the leg tried to become a straight line.

For person 2, because of the hand extension the shoulder angle and elbow angle increase then in decreases as it started to be flexion. At the meantime, knee angle fluctuated within the range of 150˚ to 180˚. Hip angle shows a little fall when hand was extended. Hip and knee angle fluctuated in same condition.

For person 3, from the elbow and shoulder angle of displacement it can be seen that the movement rotates a lot with high rise and fall, while hip swings with small angular displacement while in flexion. And knee joint is don’t become straight so therefore, the angle changes with small variation.

For person 4, keeping knee and hip angle nearly unchanged, elbow and shoulder joint varies but is in synchronization. Sometimes, knee angle changes to beyond 180˚, it is due to twist given by hip-knee segment away from camera while keeping leg straight.

For person 5, the elbow and shoulder angle move with higher and lower variation. The shoulder angle goes beyond 0˚ which means the shoulder to elbow segment crosses the trunk segment. Otherwise, hip and knee angle vary correctly within the flexion range.

For person 6, here, the knee angle doesn’t change much. Hip angle shows swings with low twist in waist. Elbow angle has maximum displacement and shoulder angle has the lower displacement.

For person 7, here, the hip angle changes from high value to lower value then it tried to keep itself in rhythm. Knee angle also changed into higher to low value then keep it nearly unchanged. Elbow and shoulder angle changed in same displacement. Shoulder angle goes nearly up to 0˚ which means trunk segment and shoulder elbow segment fall in same line for some times then again it rises.

For person 8, elbow and shoulder angle displaced with valid synchronization. The hip and knee angle changes against elbow, shoulder angle with minimal deflection.

For person 9, knee angle and hip angle doesn't change much but elbow angle and shoulder angle changes drastically. Here again shoulder angle goes beyond to 0˚ which means the shoulder elbow segment overlapped trunk segment.

For person 10, the elbow and shoulder angle show increase and decrease in value due to extension and flexion. Hip angle with minimal deflection so twist is less. Same goes for knee angle.

For person 11, knee angle ranges from 170˚ to 190˚, it is due to high swing with twist in hip. Hip angle remains nearly unchanged. The elbow and shoulder angle shows varying angular displacement.

For person 12, hip angle and knee angle shows the angular displacement with minimal deflection. Knee angle Going beyond 180˚ is because of the swing away from camera. The elbow and shoulder angle show its changes dramatically. Shoulder Joint goes beyond 0˚ therefore, again the shoulder elbow segment crosses trunk segment.

5.4 Graphical Representation of Joint Displacement and Velocity

1) Horizontal Position:

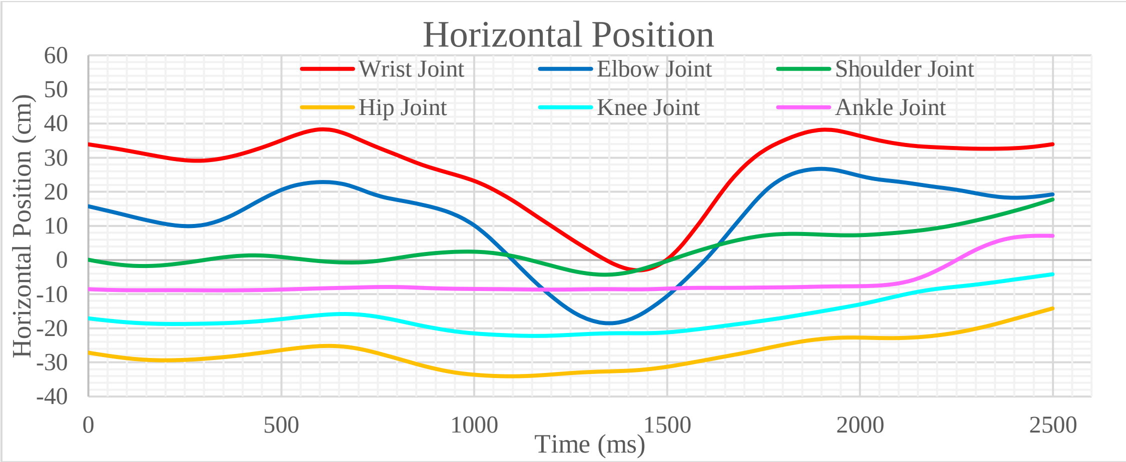

Figure 5-4 Horizontal Position of joint for person 1

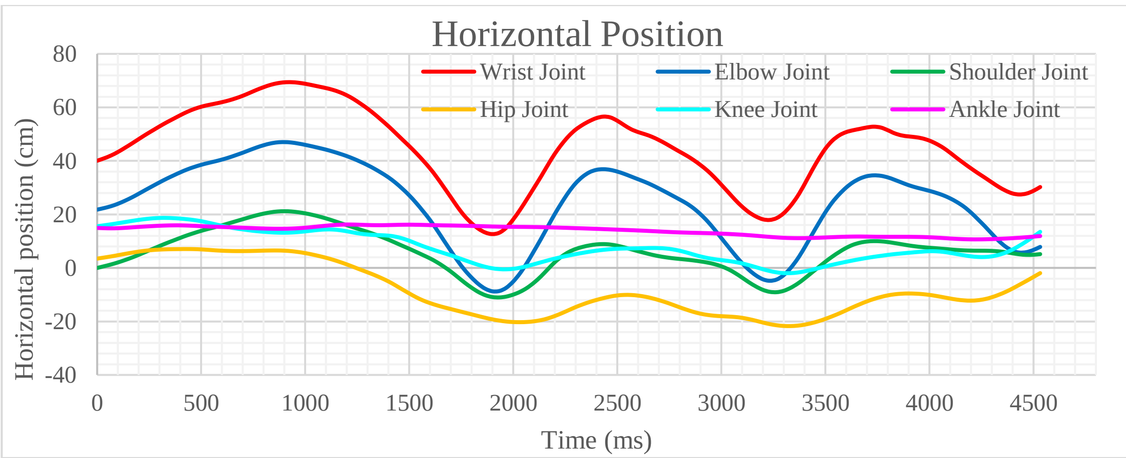

Figure 5-5 Horizontal Position of joint for person 2

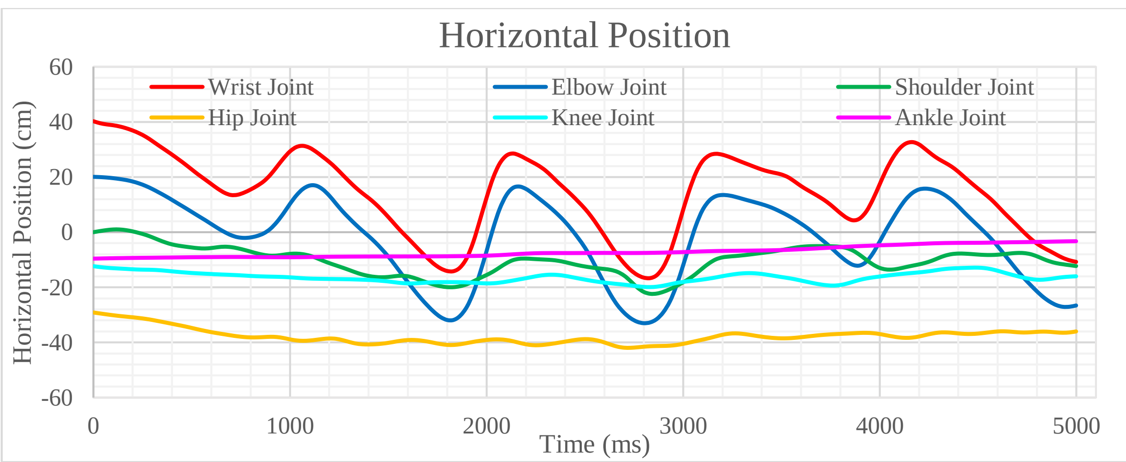

Figure 5-6 Horizontal Position of joint for person 3

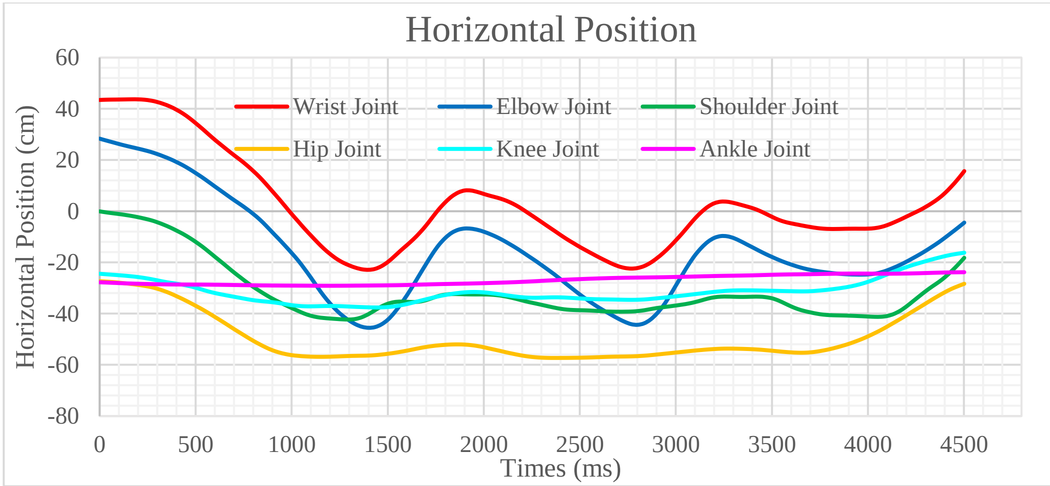

Figure 5-7 Horizontal Position of joint for person 4

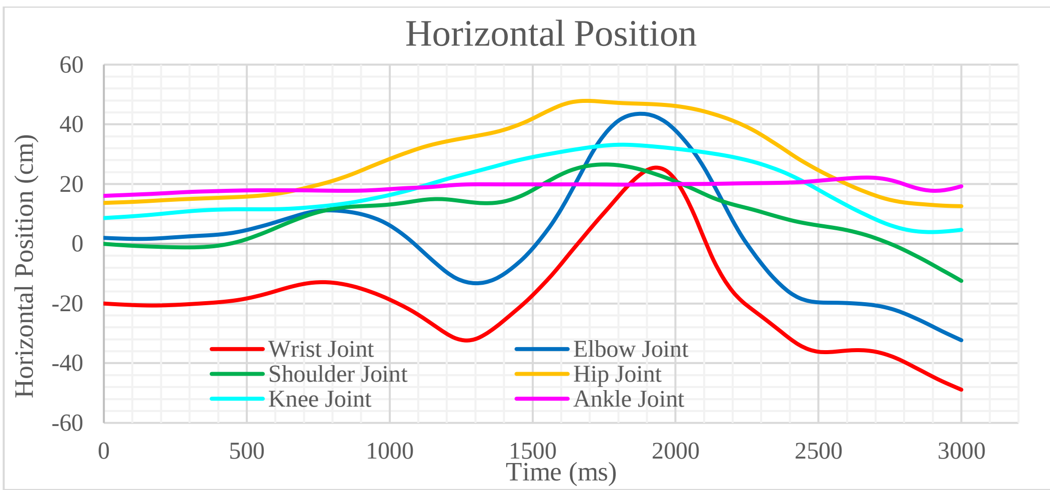

Figure 5-8 Horizontal Position of joint for person 5

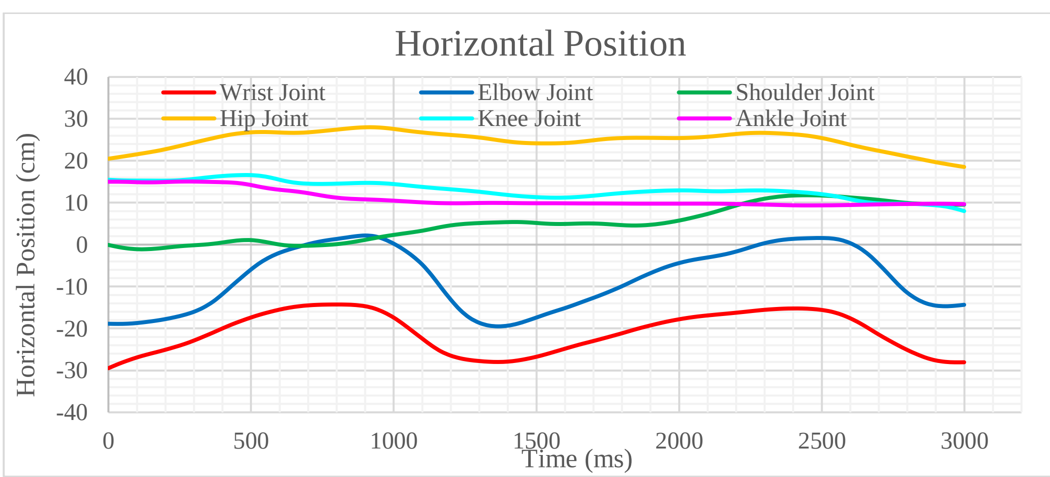

Figure 5-9 Horizontal Position of joint for person 6

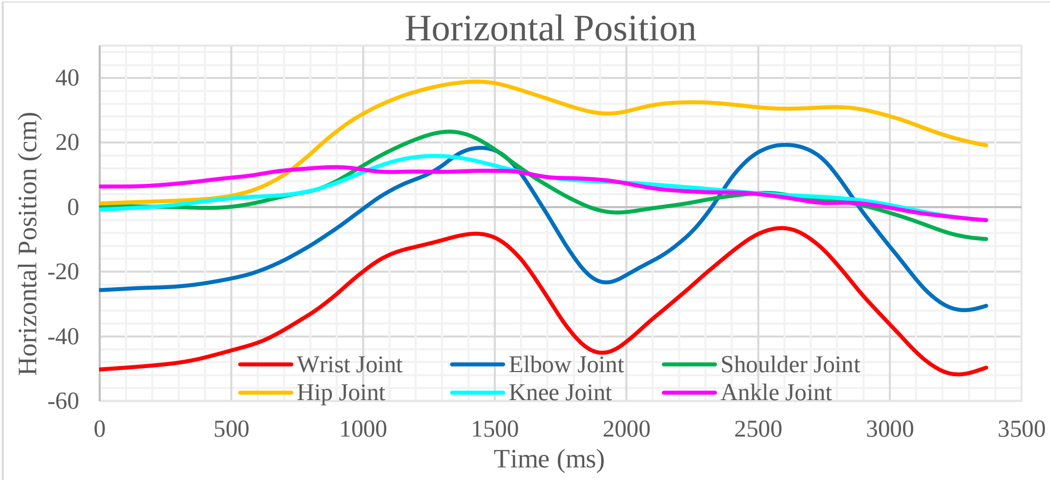

Figure 5-10 Horizontal Position of joint for person 7

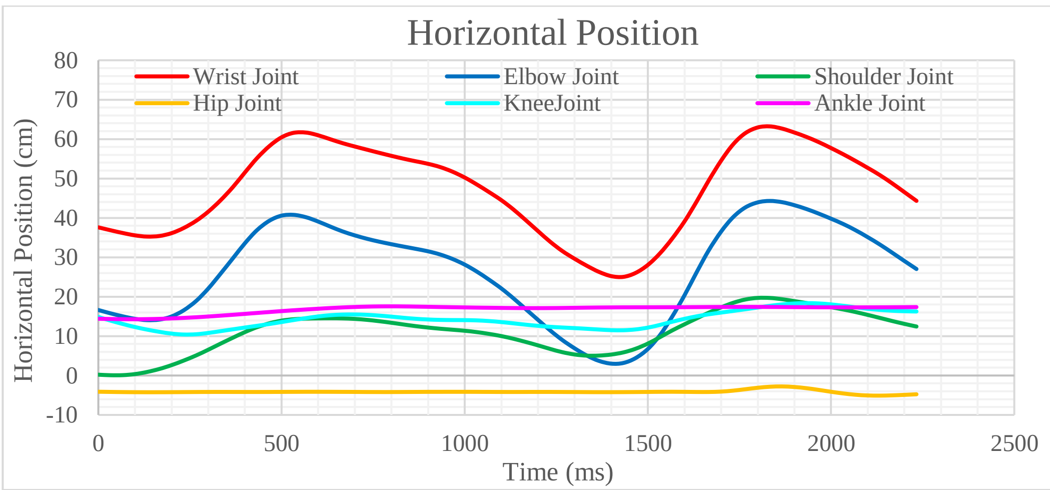

Figure 5-11 Horizontal Position of joint for person 8

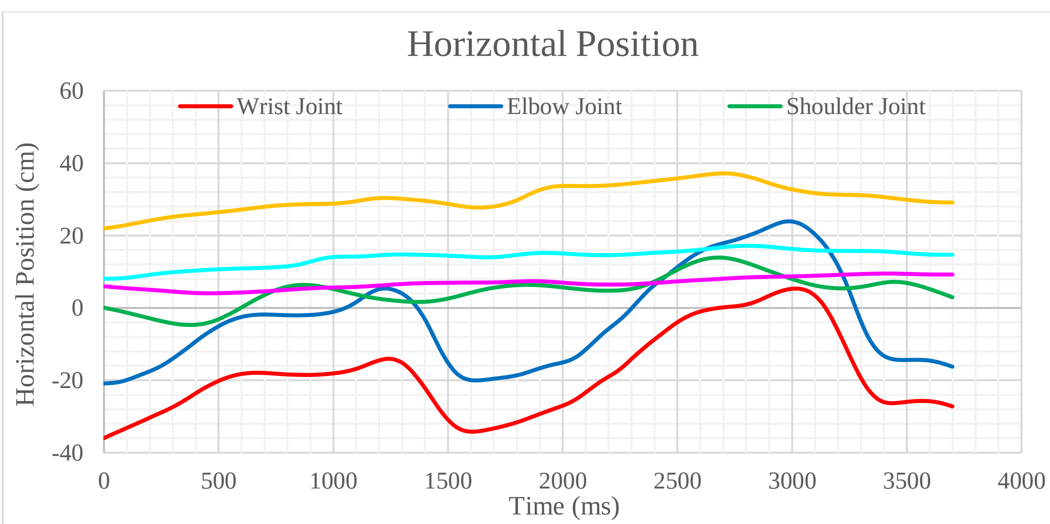

Figure 5-12 Horizontal Position of joint for person 9

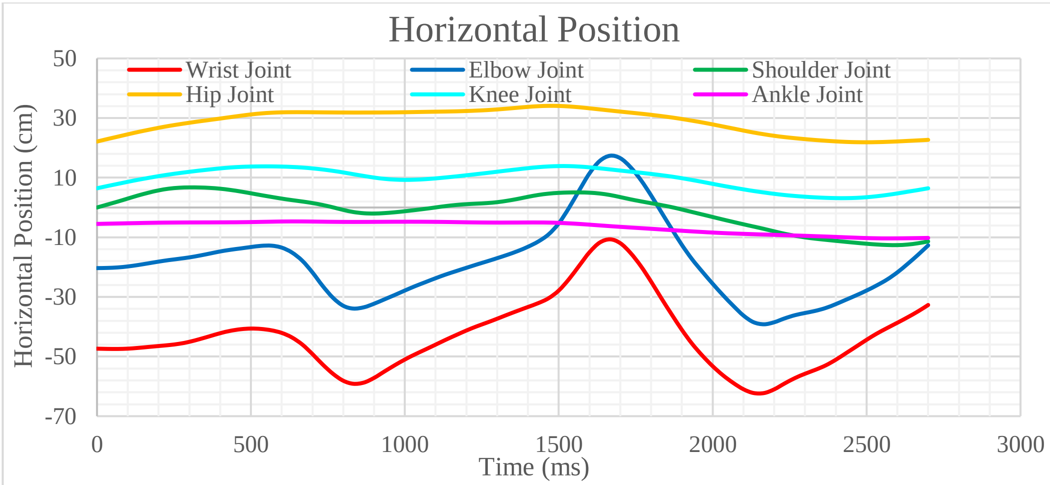

Figure 5-13 Horizontal Position of joint for person 10

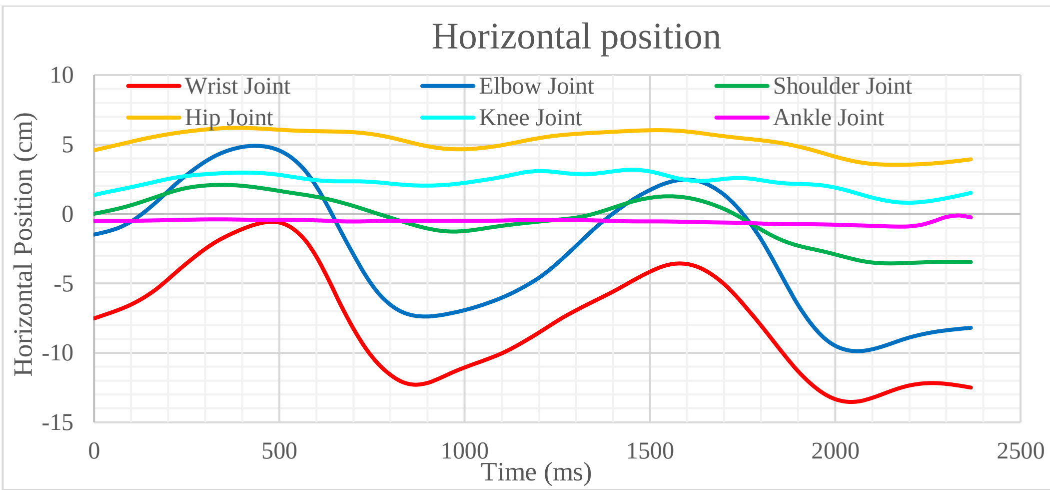

Figure 5-14 Horizontal Position of joint for person 11

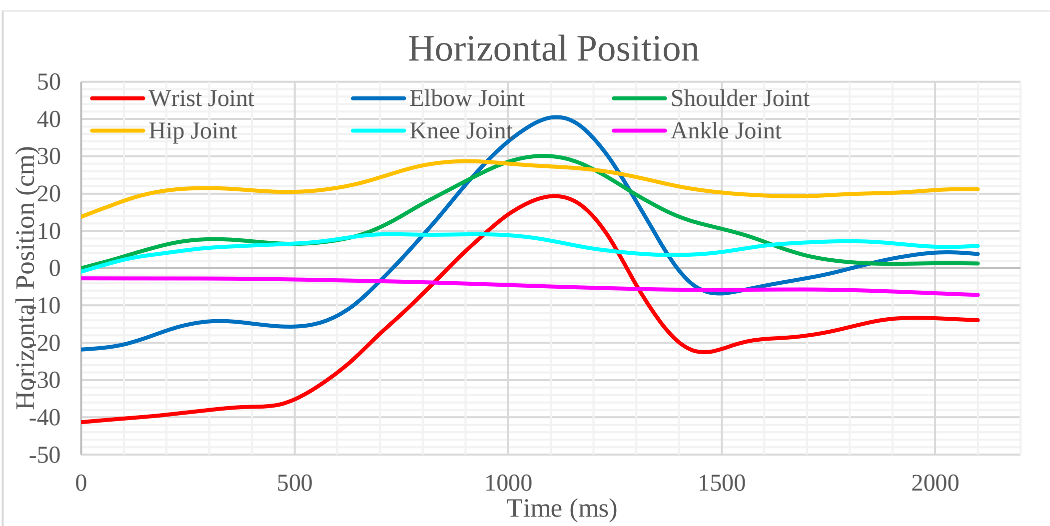

Figure 5-15 Horizontal Position of joint for person 12

2) Vertical Position:

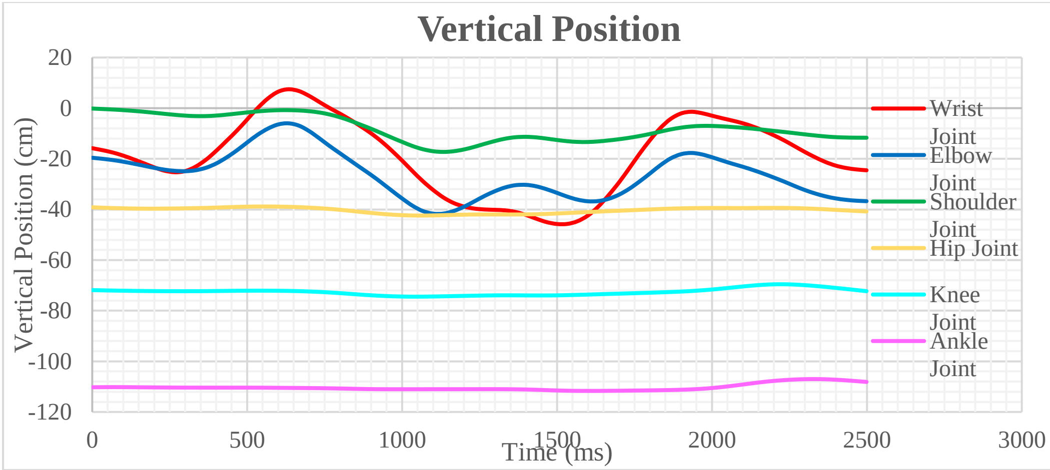

Figure 5-16 Vertical Position of joint for person 1

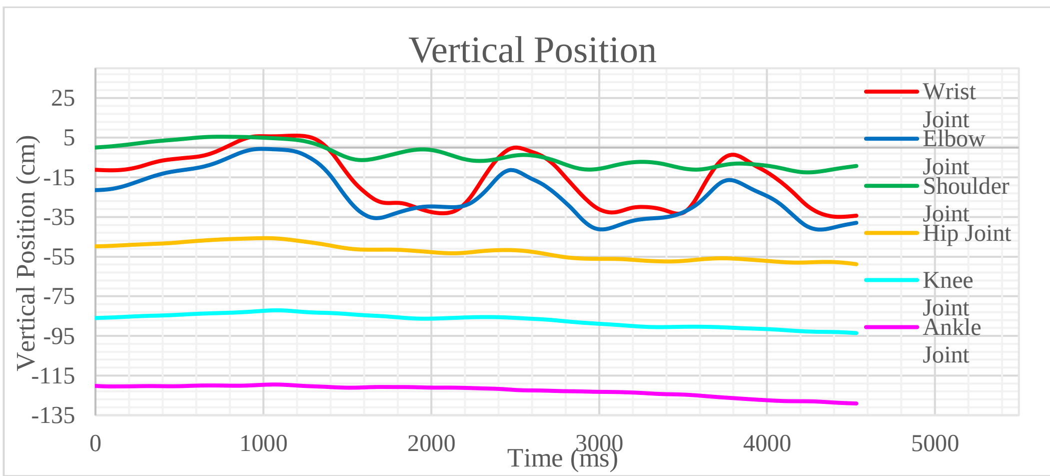

Figure 5-17 Vertical Position of joint for person 2

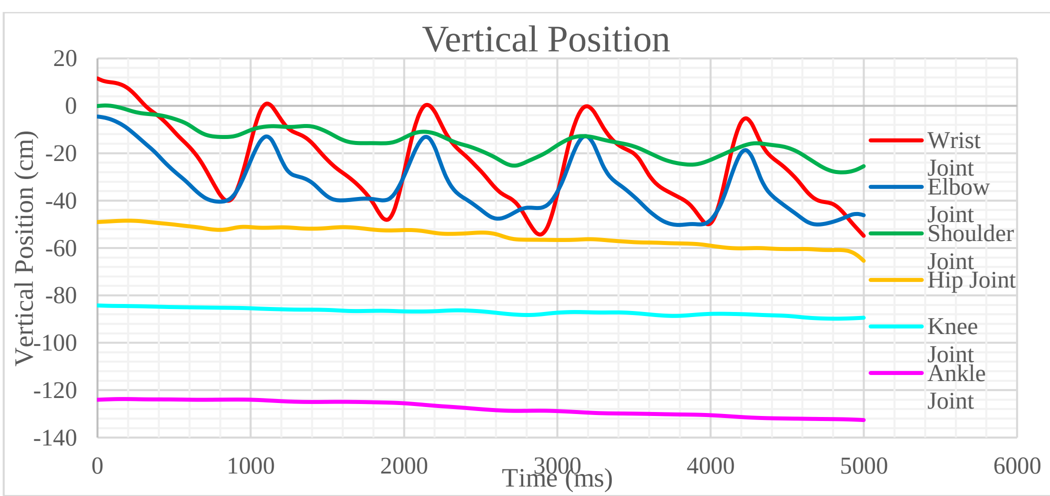

Figure 5-18 Vertical Position of joint for person 3

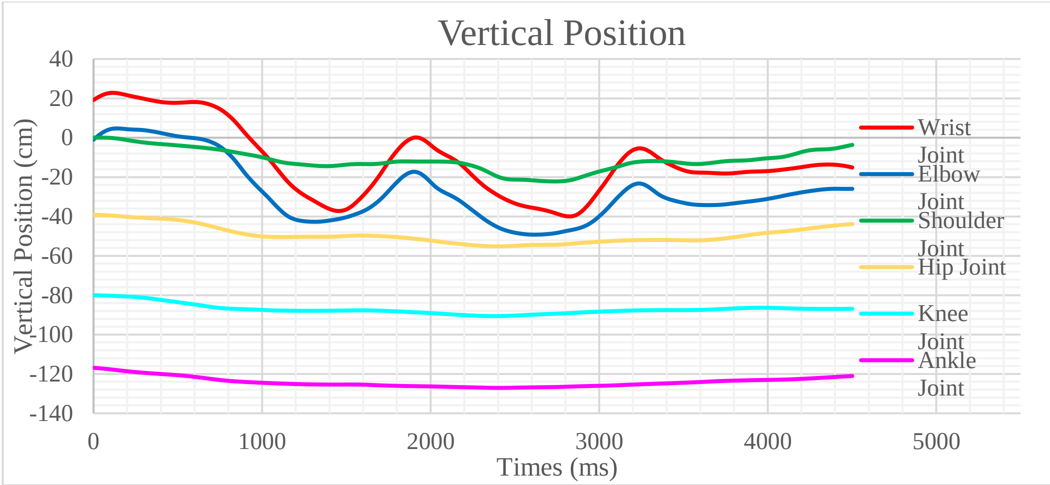

Figure 5-19 Vertical Position of joint for person 4

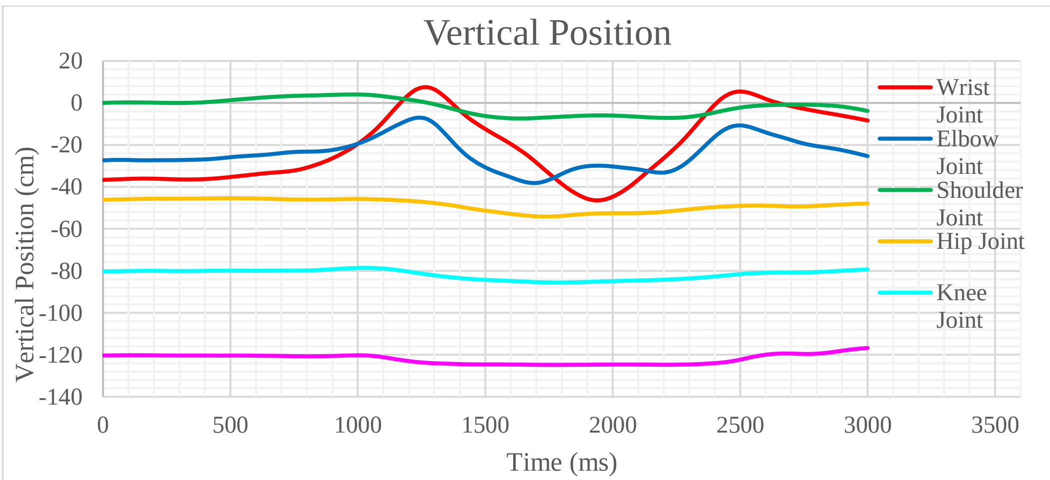

Figure 5-20 Vertical Position of joint for person 5

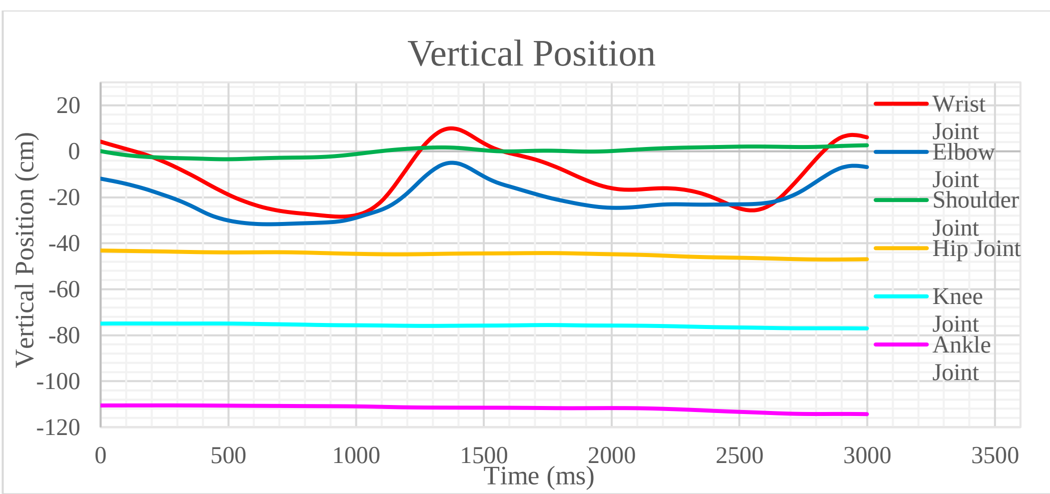

Figure 5-21 Vertical Position of joint for person 6

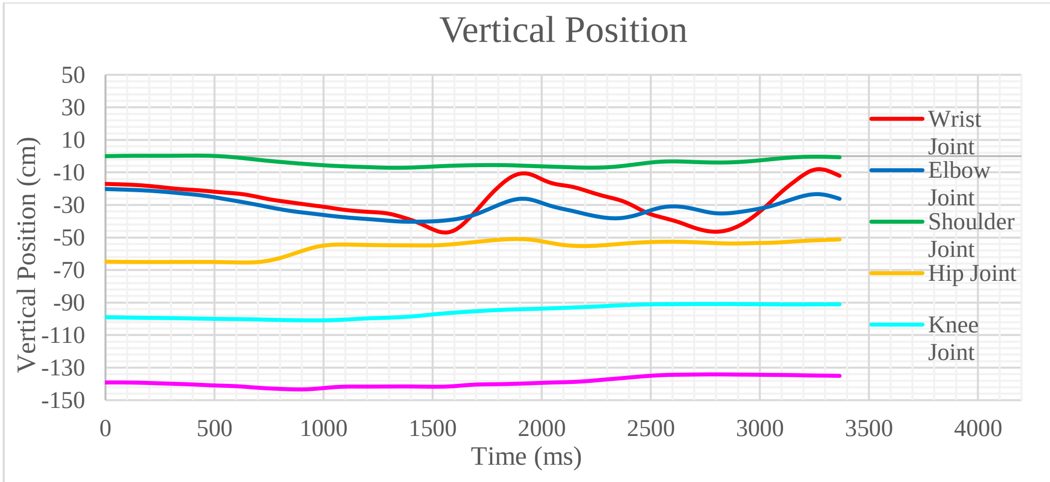

Figure 5-22 Vertical Position of joint for person 7

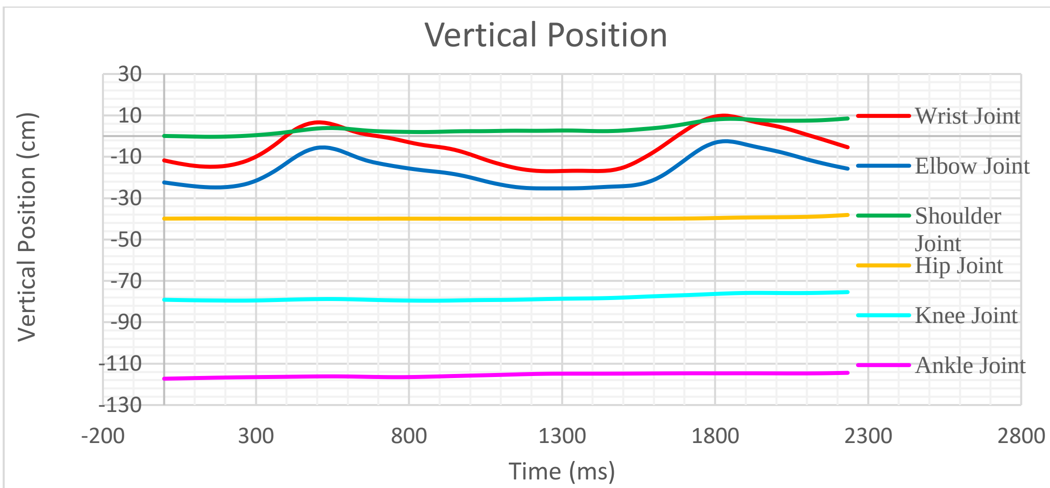

Figure 5-23 Vertical Position of joint for person 8

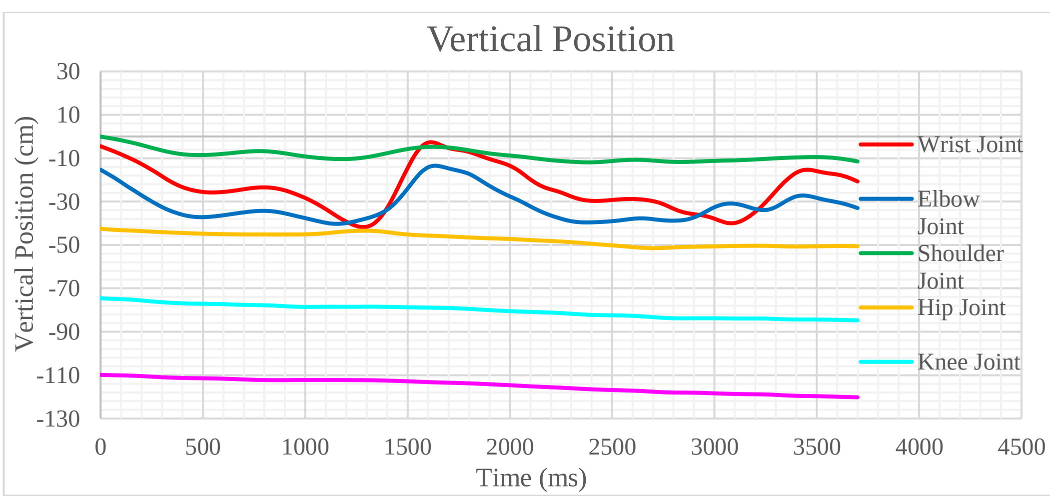

Figure 5-24 Vertical Position of joint for person 9

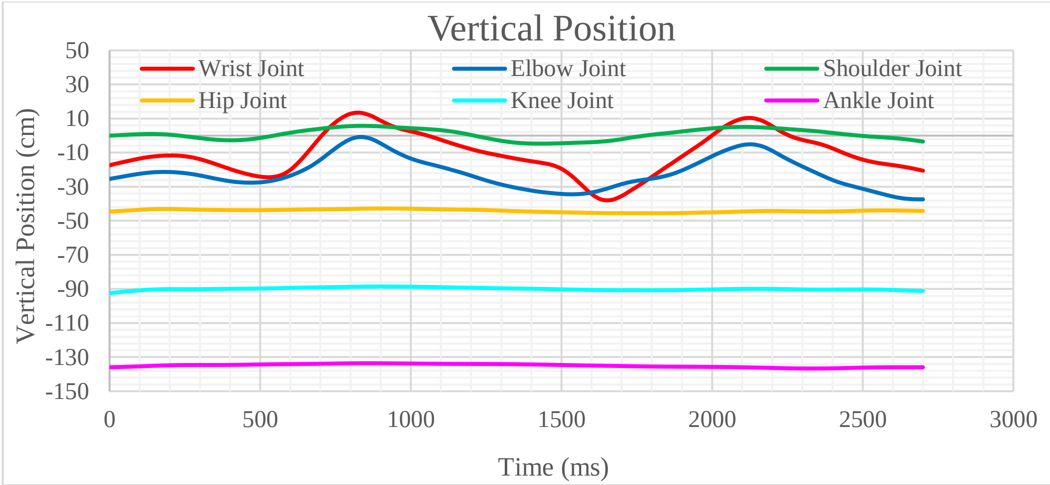

Figure 5-25 Vertical Position of joint for person 10

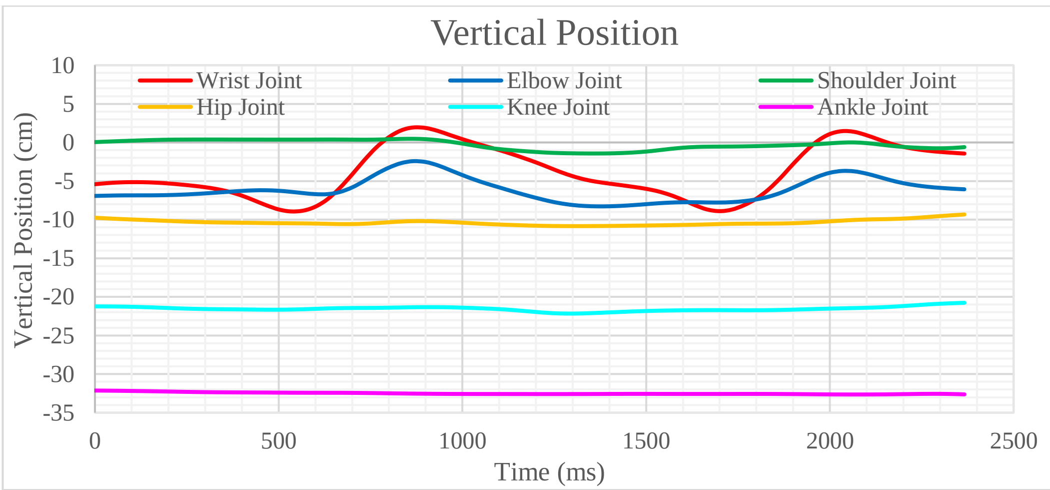

Figure 5-26 Vertical Position of joint for person 11

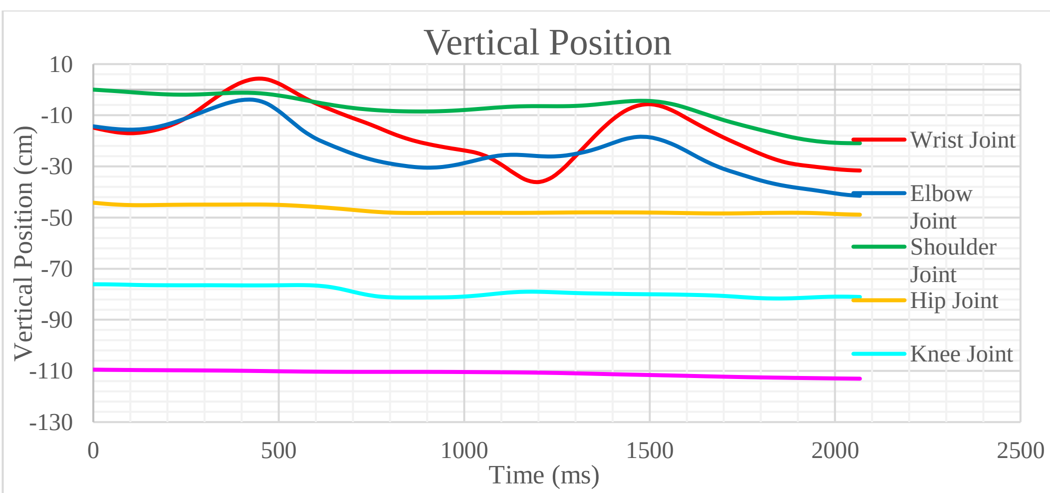

Figure 5-27 Vertical Position of joint for person 12

3) Total Distance:

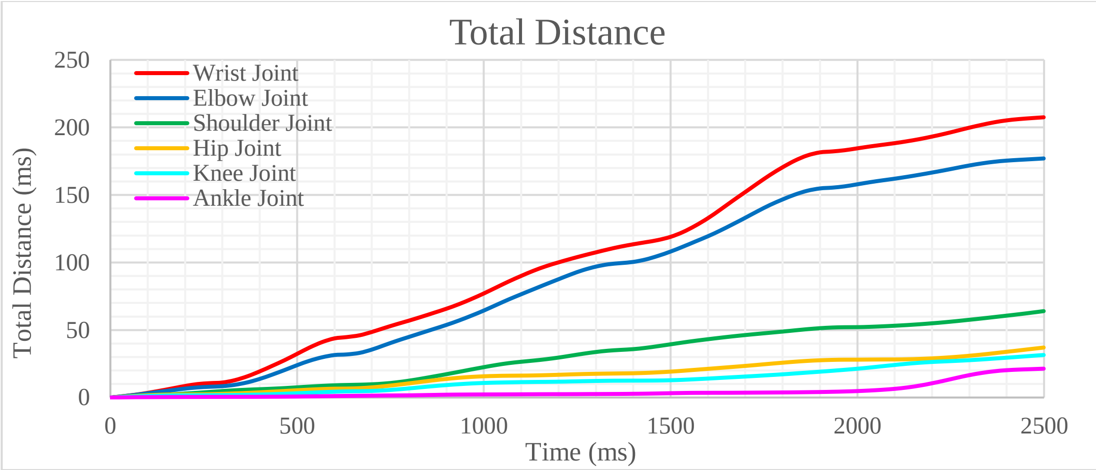

Figure 5-28 Total distance covered by joint of person 1

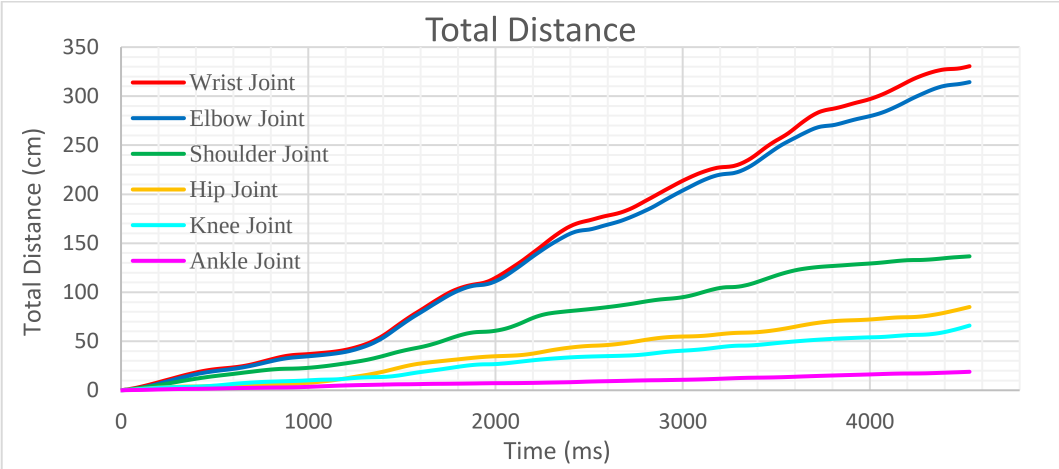

Figure 5-29 Total distance covered by joint of person 2

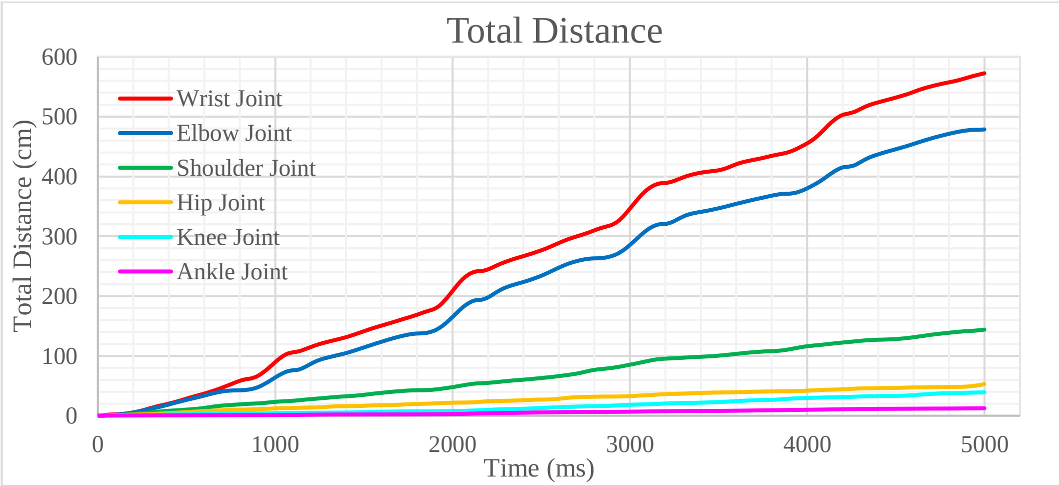

Figure 5-30 Total distance covered by joint of person 3

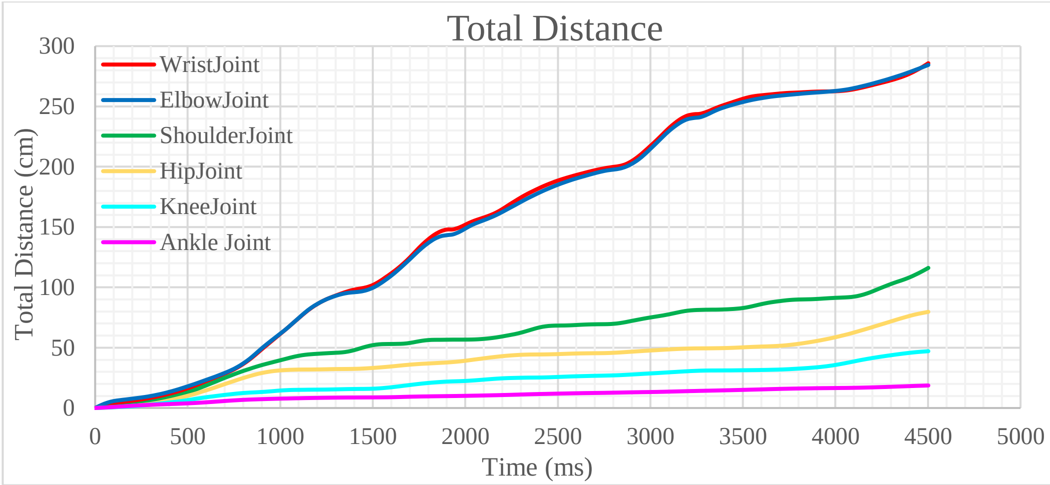

Figure 5-31 Total distance covered by joint of person 4

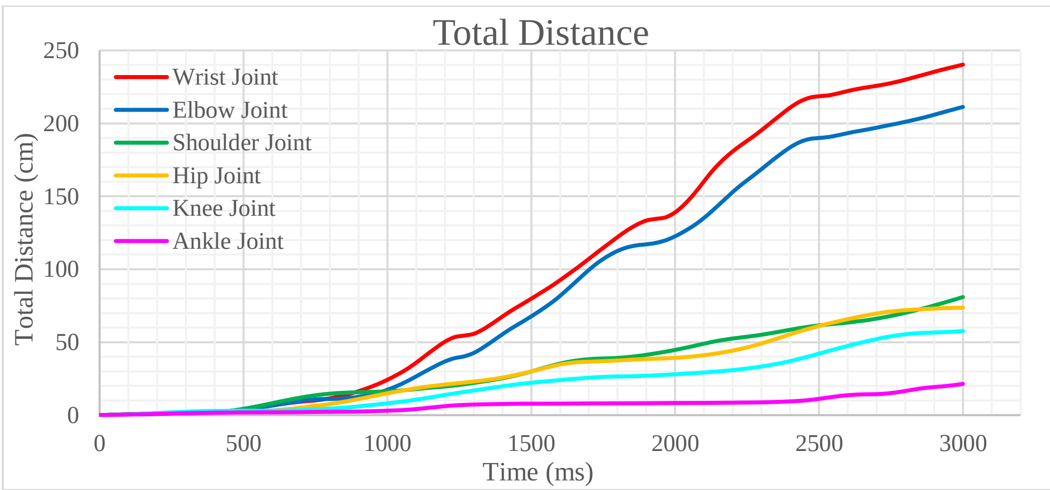

Figure 5-32 Total distance covered by joint of person 5

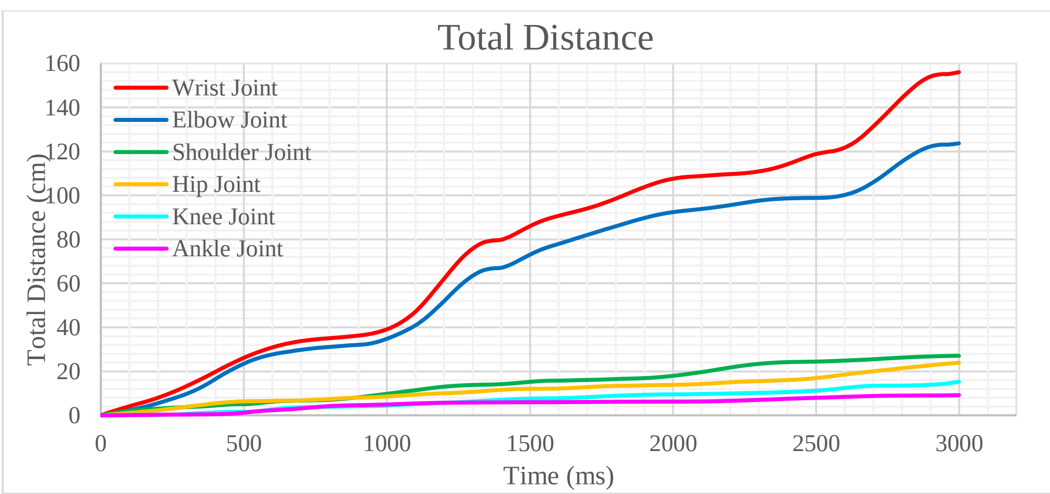

Figure 5-33 Total distance covered by joint of person 6

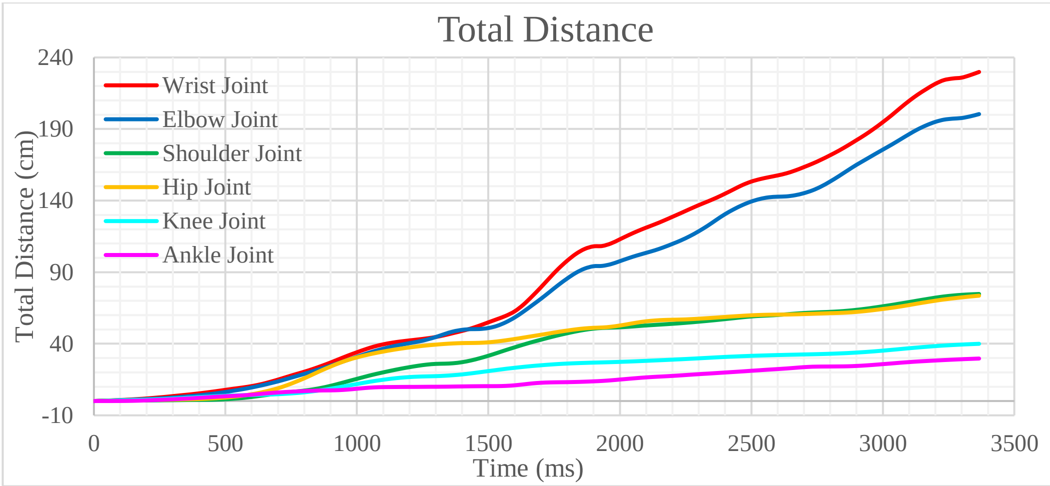

Figure 5-34 Total distance covered by joint of person 7

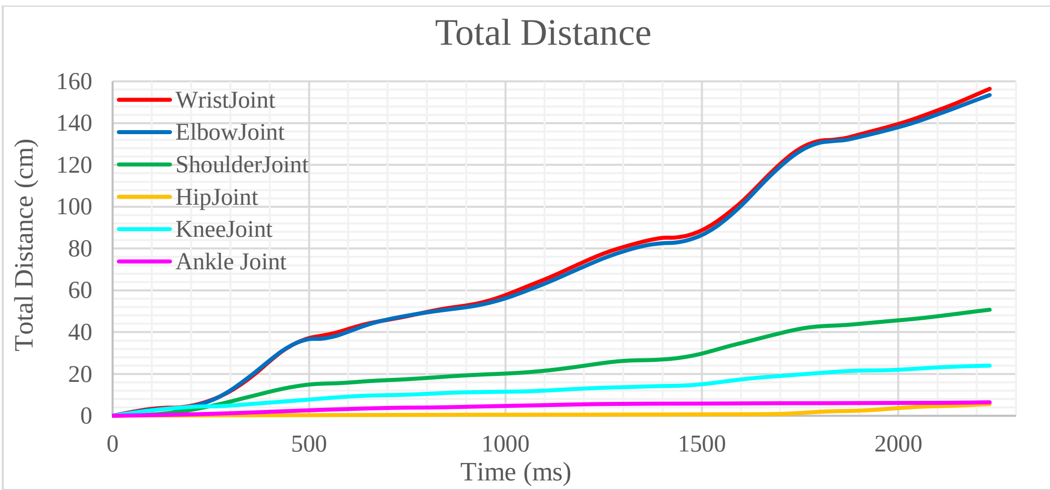

Figure 5-35 Total distance covered by joint of person 8

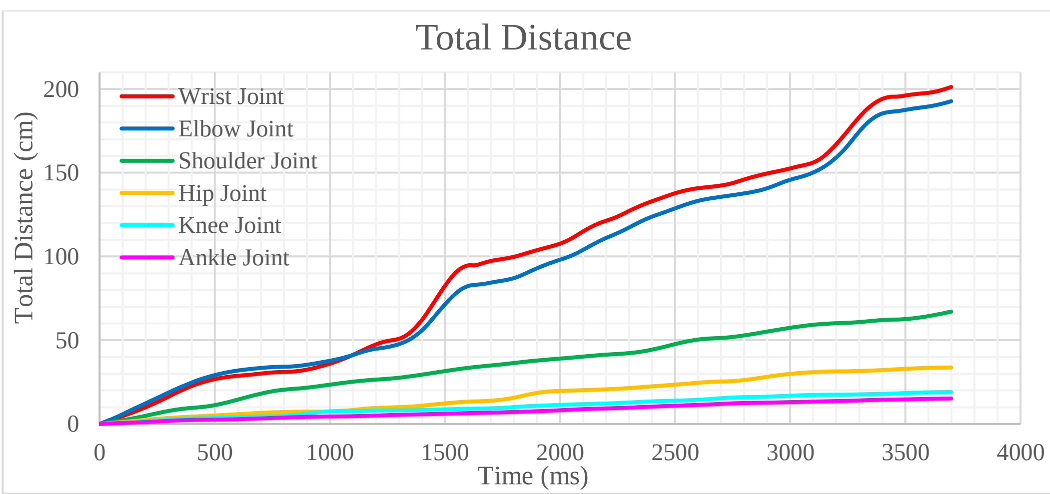

Figure 5-36 Total distance covered by joint of person 9

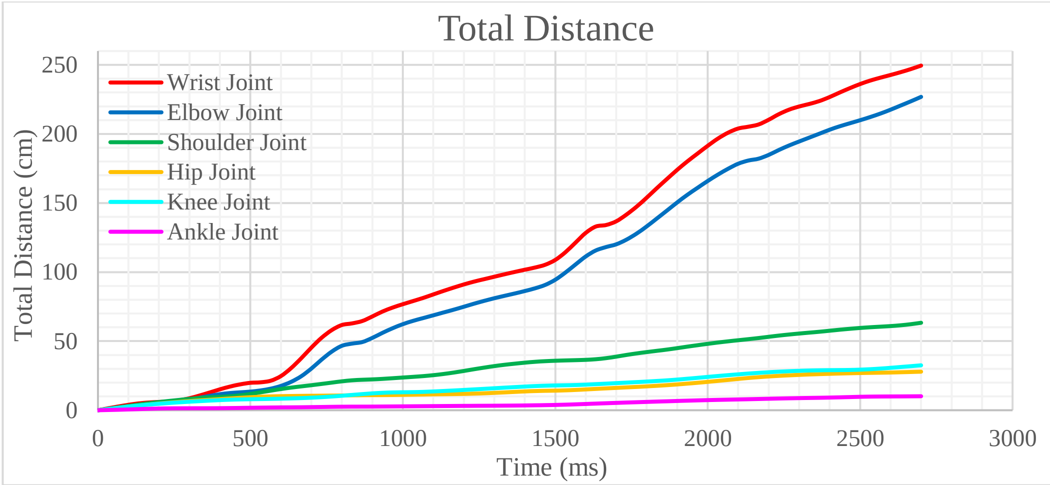

Figure 5-37 Total distance covered by joint of person 10

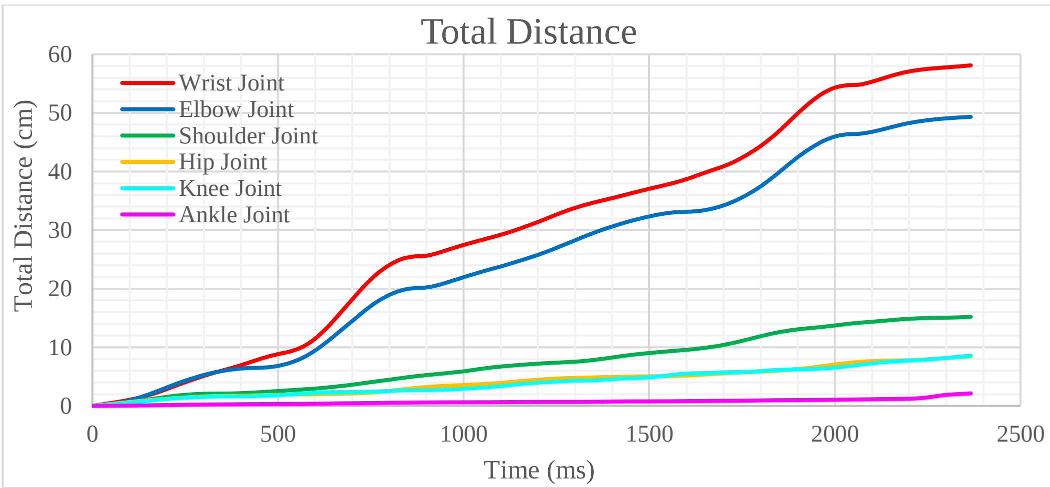

Figure 5-38 Total distance covered by joint of person 11

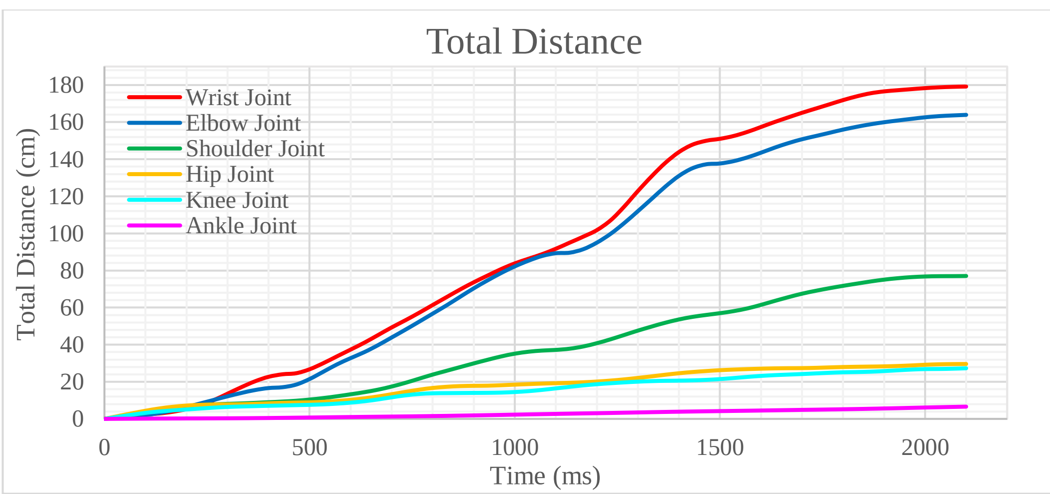

Figure 5-39 Total distance covered by joint of person 12

4) Horizontal Velocity:

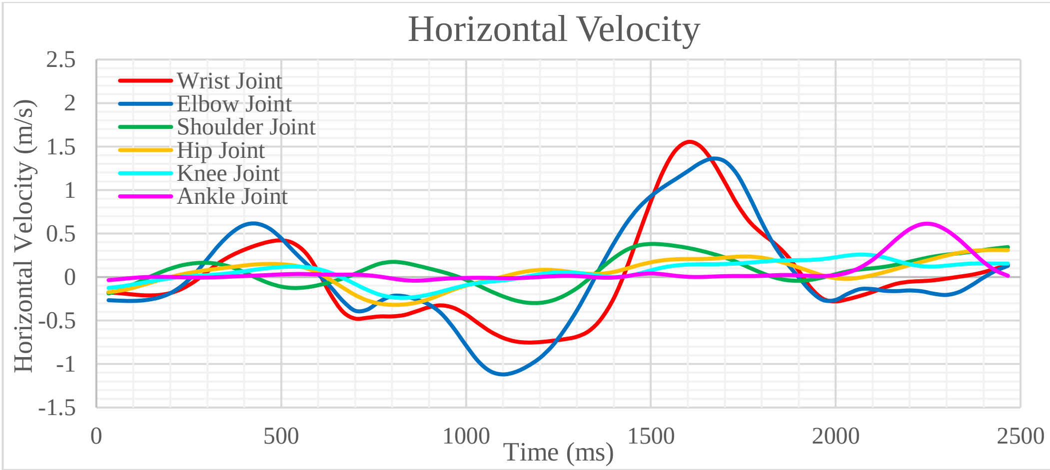

Figure 5-40 Horizontal Velocity of the joints of person 1

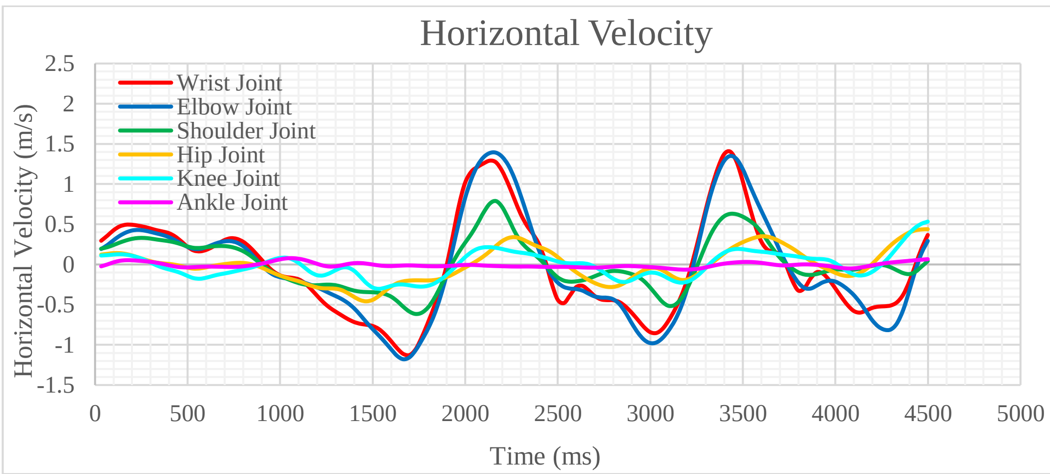

Figure 5-41 Horizontal Velocity of the joints of person 2

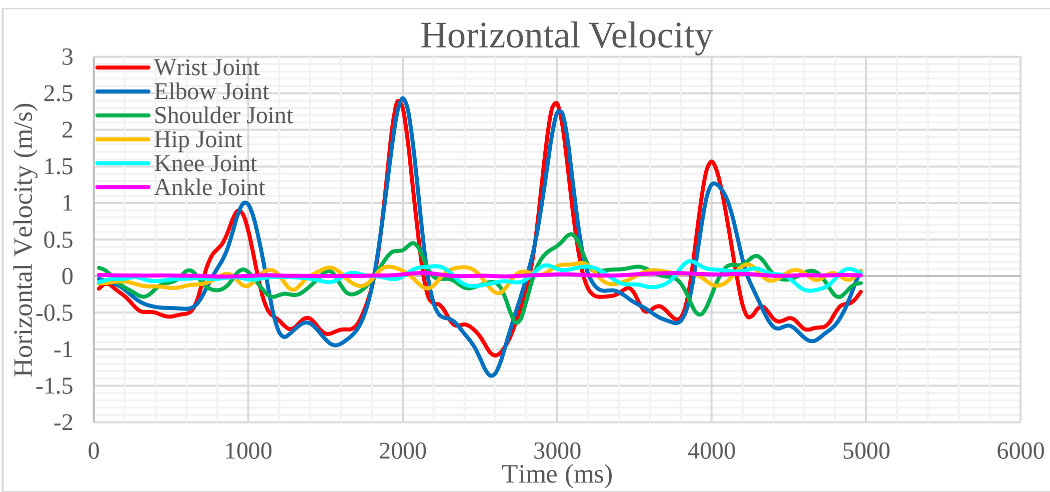

Figure 5-42 Horizontal Velocity of the joints of person 3

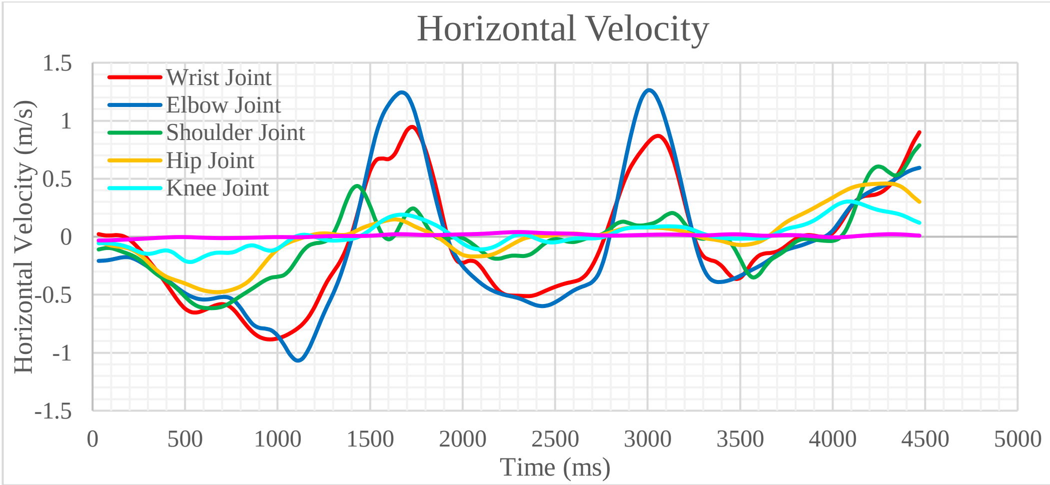

Figure 5-43 Horizontal Velocity of the joints of person 4

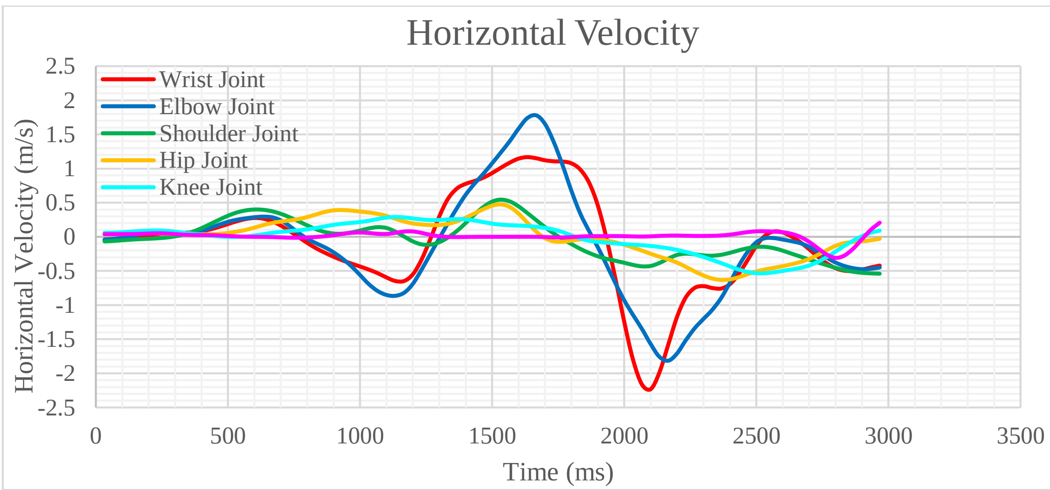

Figure 5-44 Horizontal Velocity of the joints of person 5

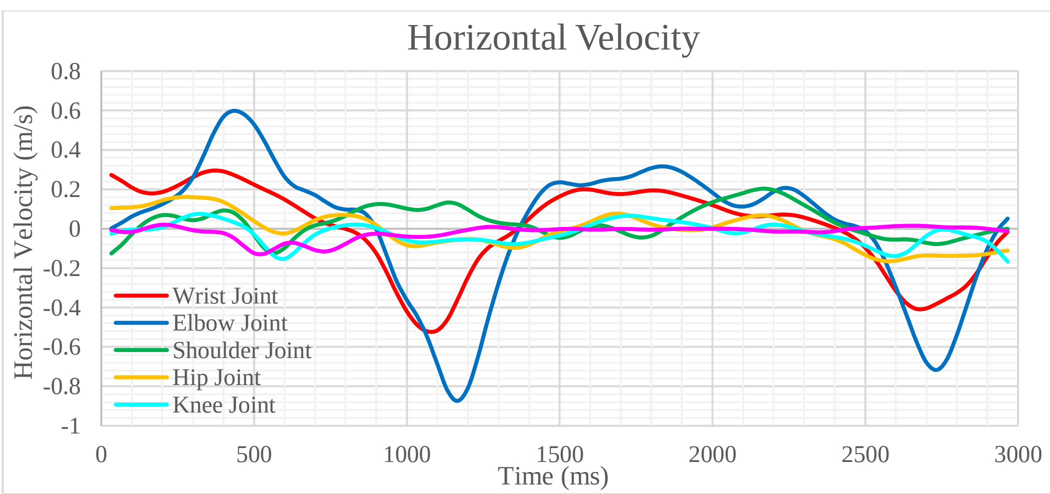

Figure 5-45 Horizontal Velocity of the joints of person 6

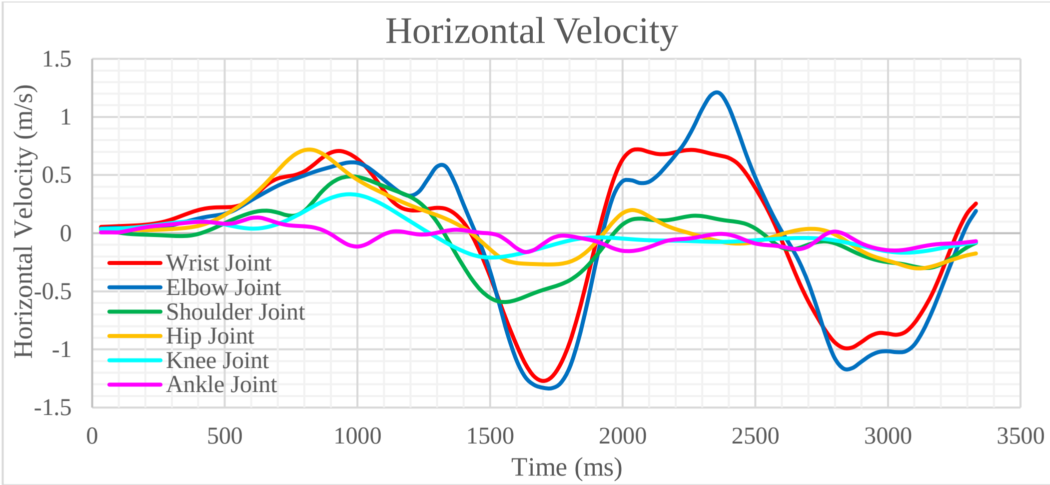

Figure 5-46 Horizontal Velocity of the joints of person 7

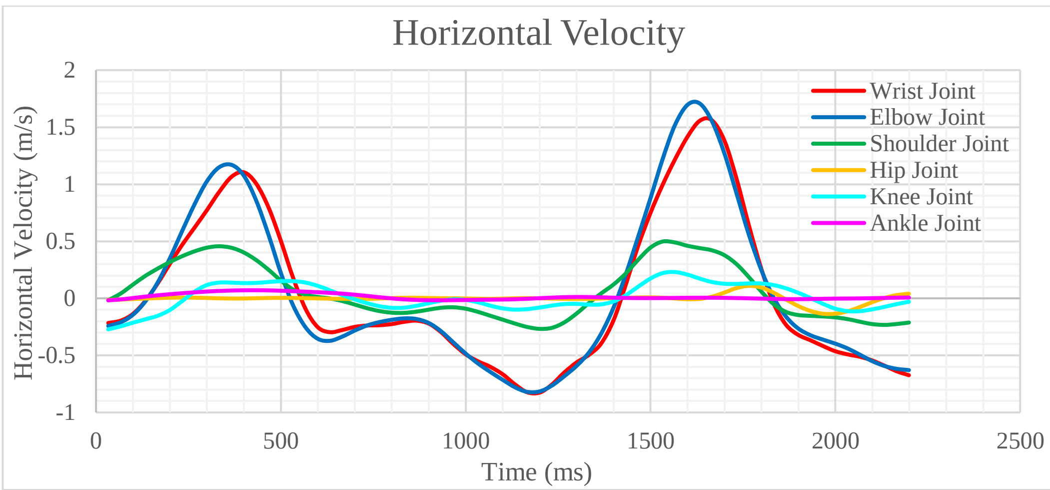

Figure 5-47 Horizontal Velocity of the joints of person 8

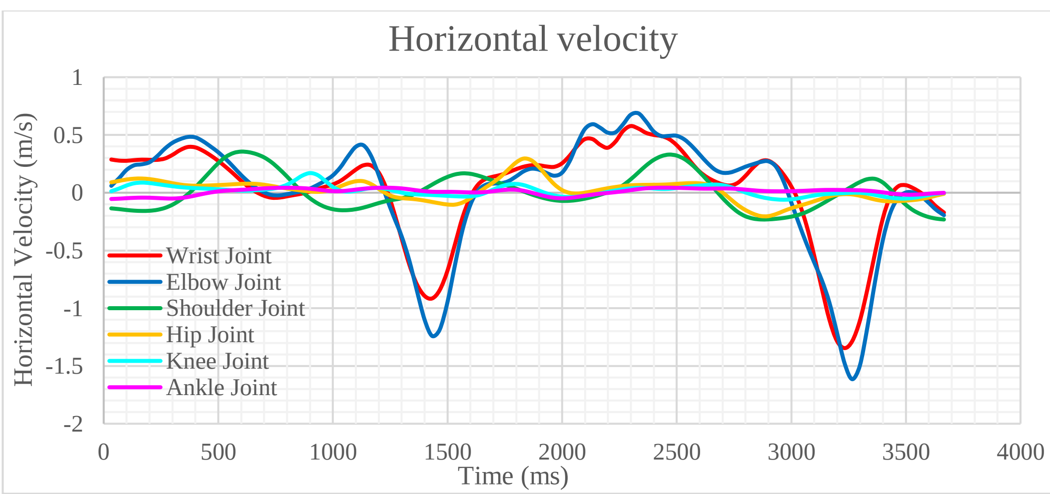

Figure 5-48 Horizontal Velocity of the joints of person 9

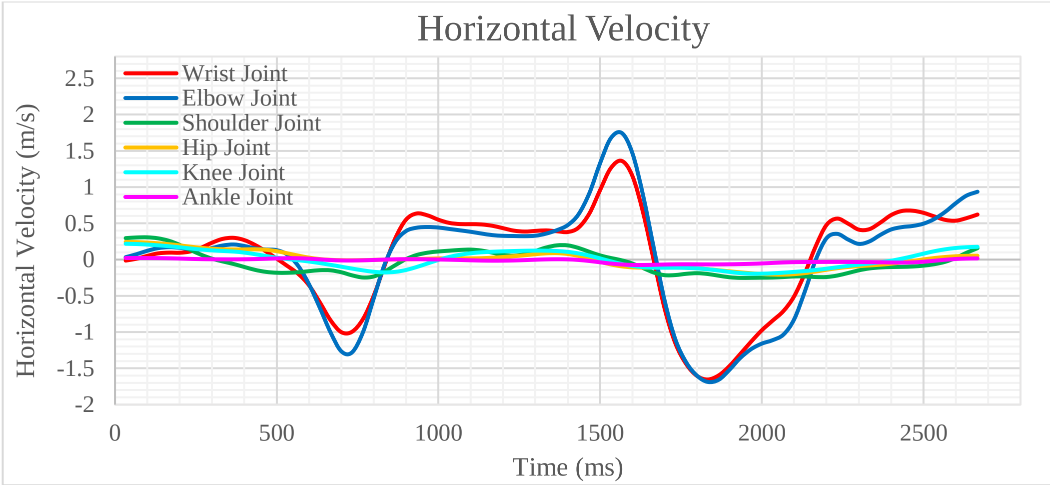

Figure 5-49 Horizontal Velocity of the joints of person 10

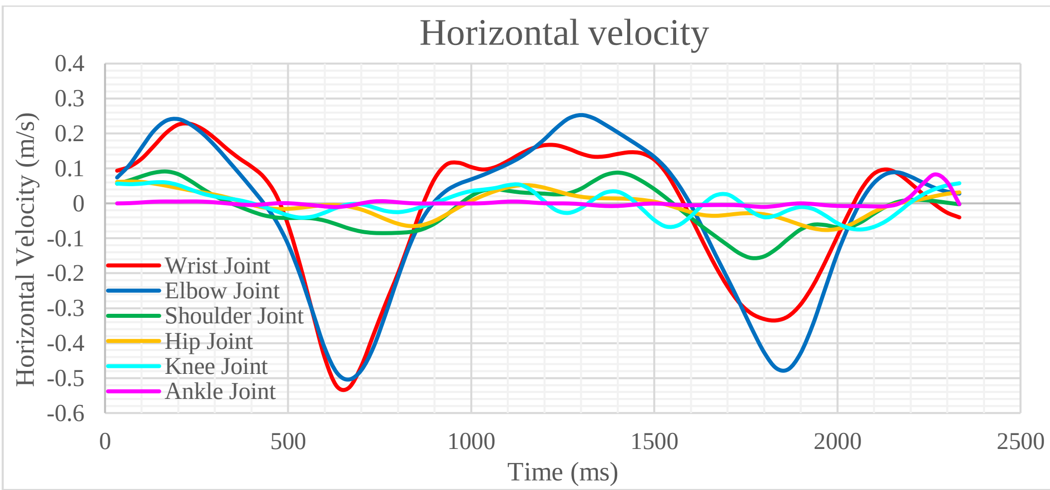

Figure 5-50 Horizontal Velocity of the joints of person 11

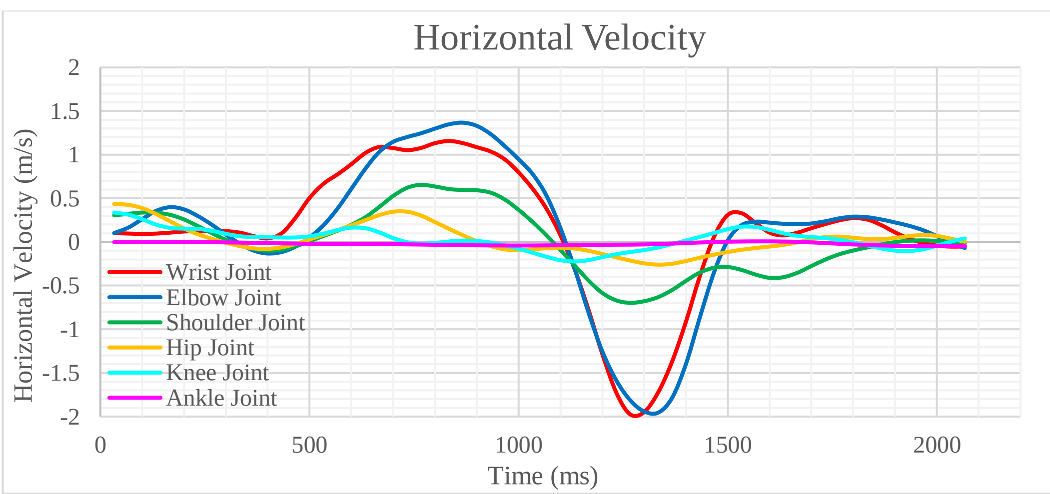

Figure 5-51 Horizontal Velocity of the joints of person 12

5) Vertical Velocity:

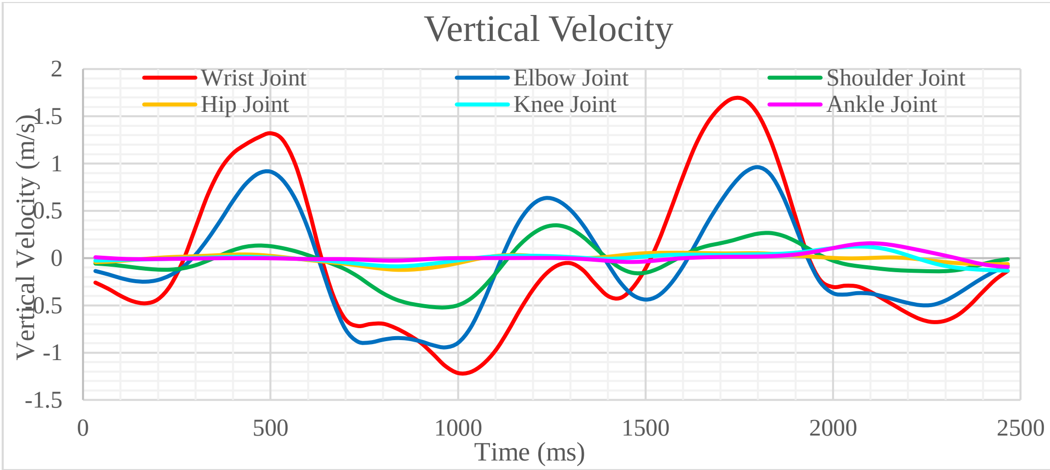

Figure 5-52 Vertical velocity of joint of person 1

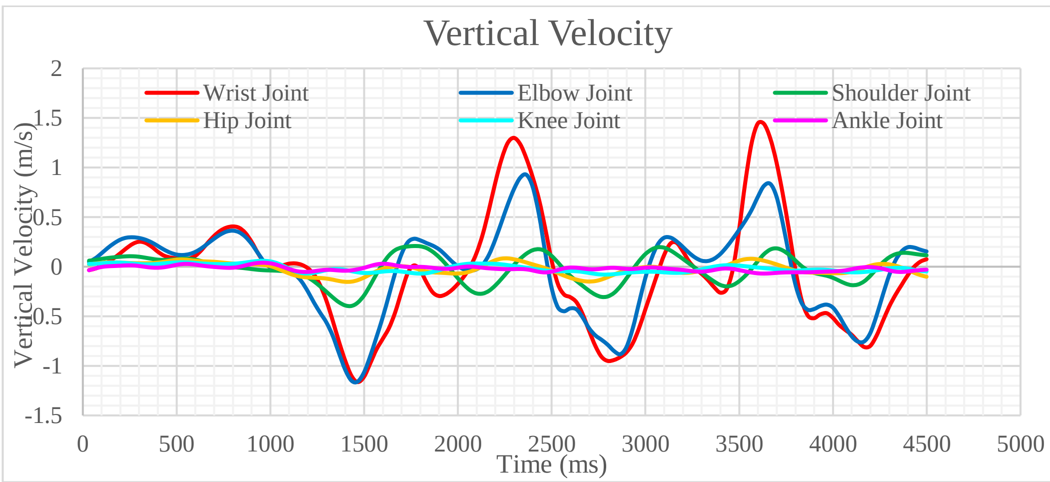

Figure 5-53 Vertical velocity of joint of person 2

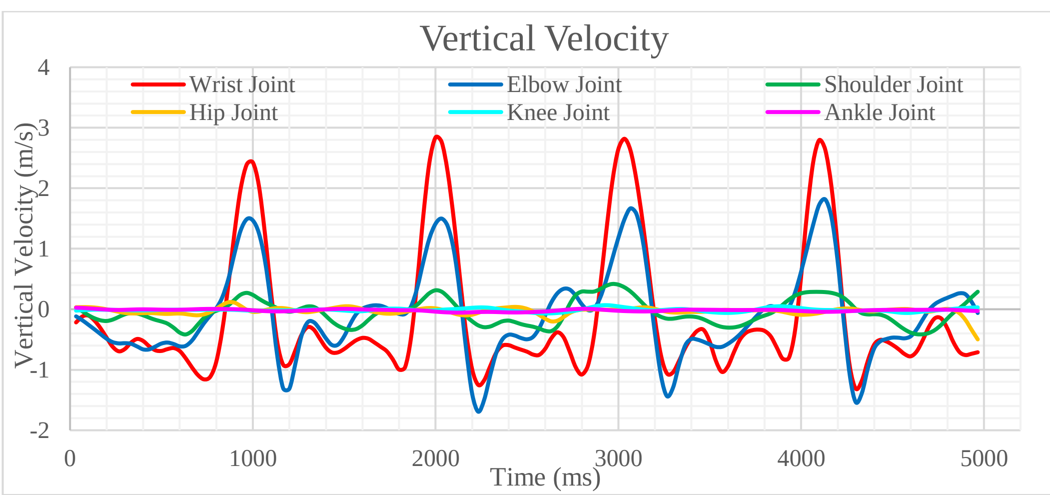

Figure 5-54 Vertical velocity of joint of person 3

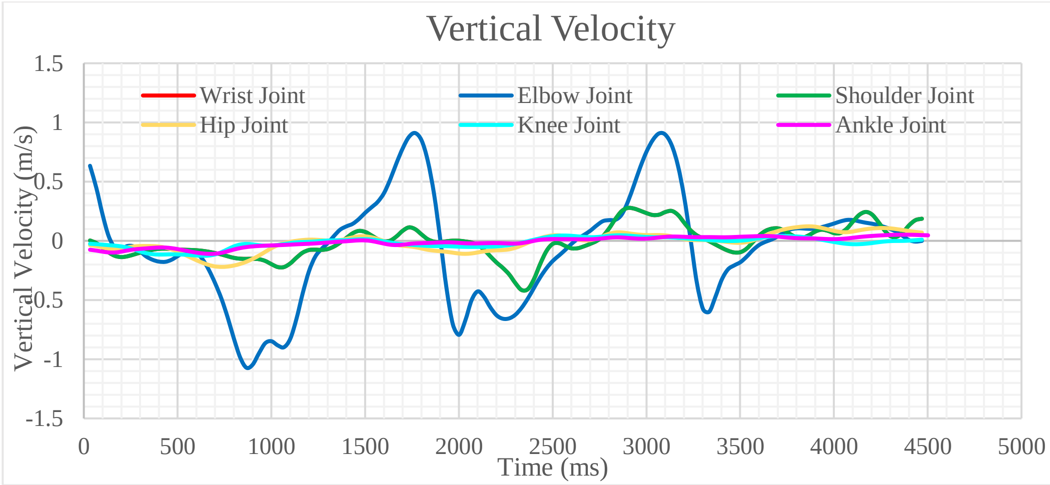

Figure 5-55 Vertical velocity of joint of person 4

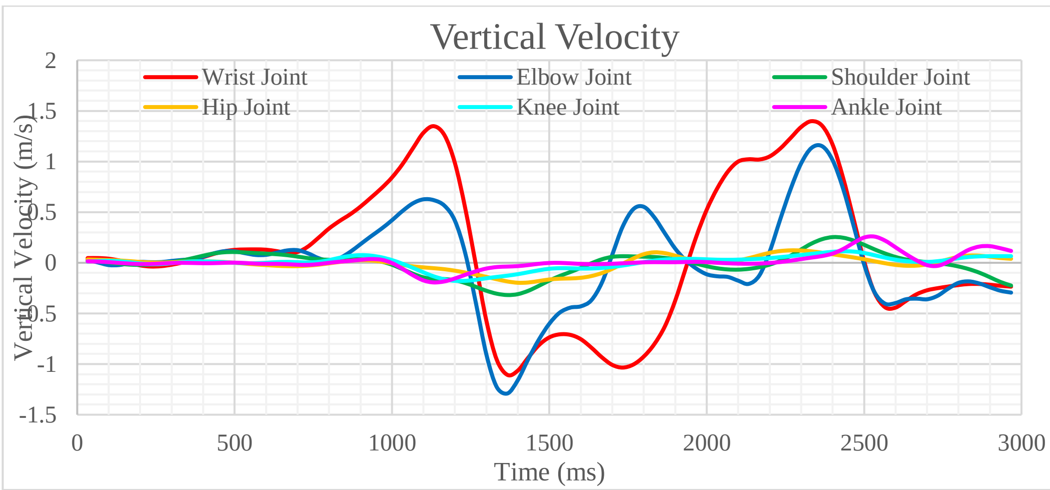

Figure 5-56 Vertical velocity of joint of person 5

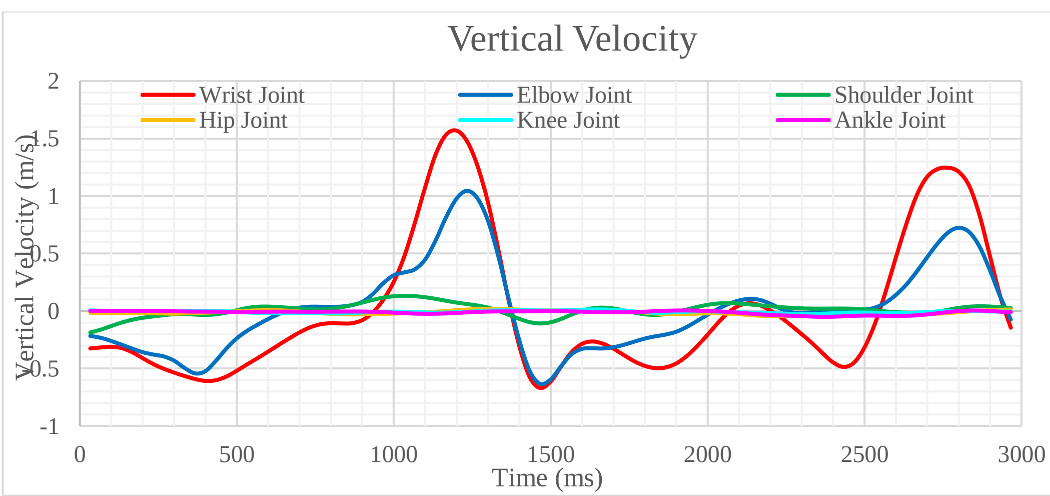

Figure 5-57 Vertical velocity of joint of person 6

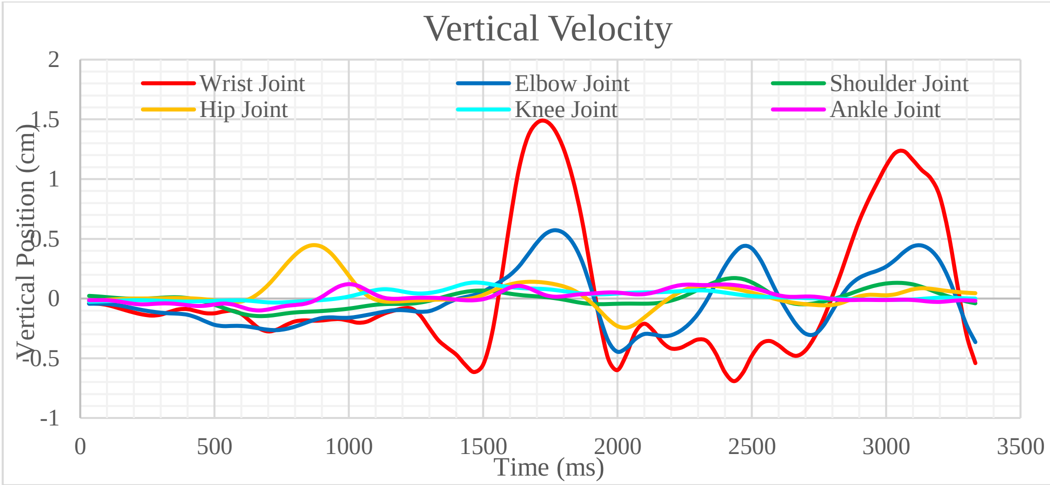

Figure 5-58 Vertical velocity of joint of person 7

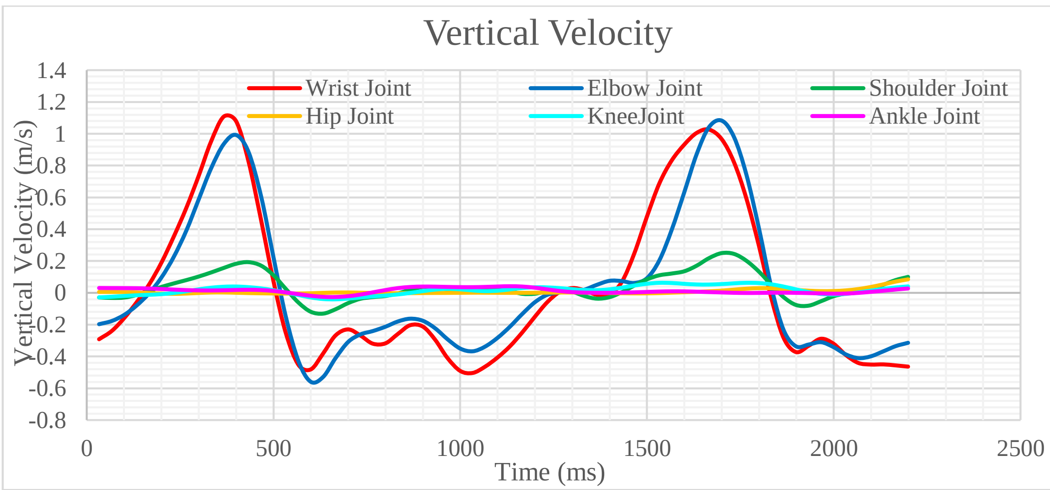

Figure 5-59 Vertical velocity of joint of person 8

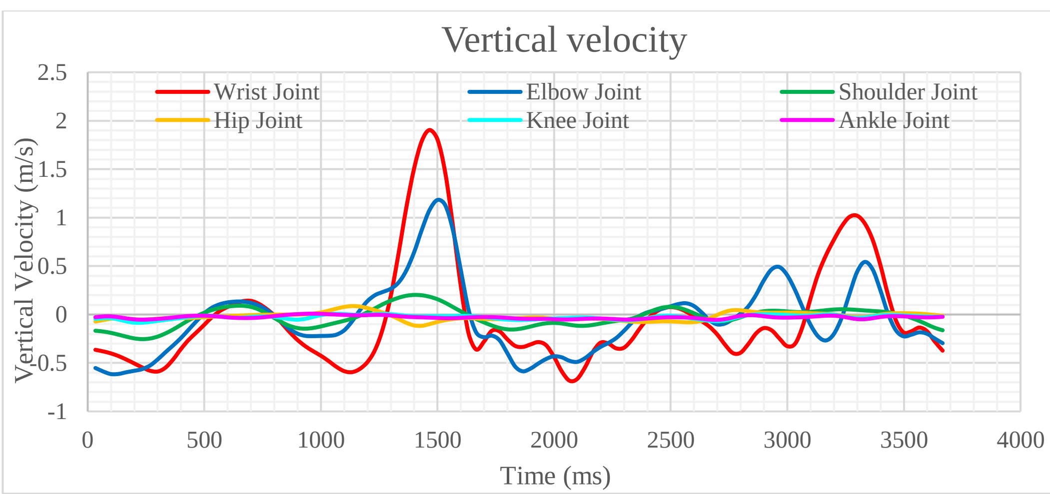

Figure 5-60 Vertical velocity of joint of person 9

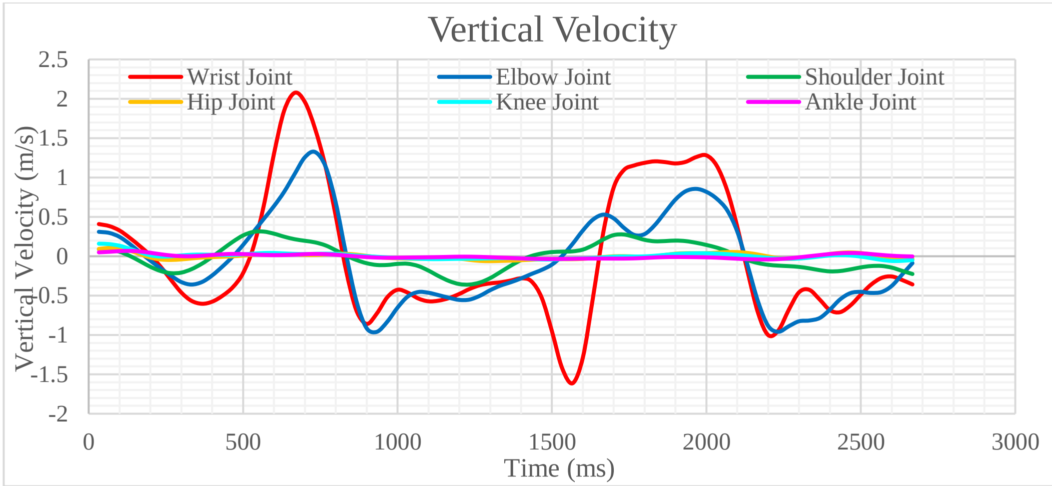

Figure 5-61 Vertical velocity of joint of person 10

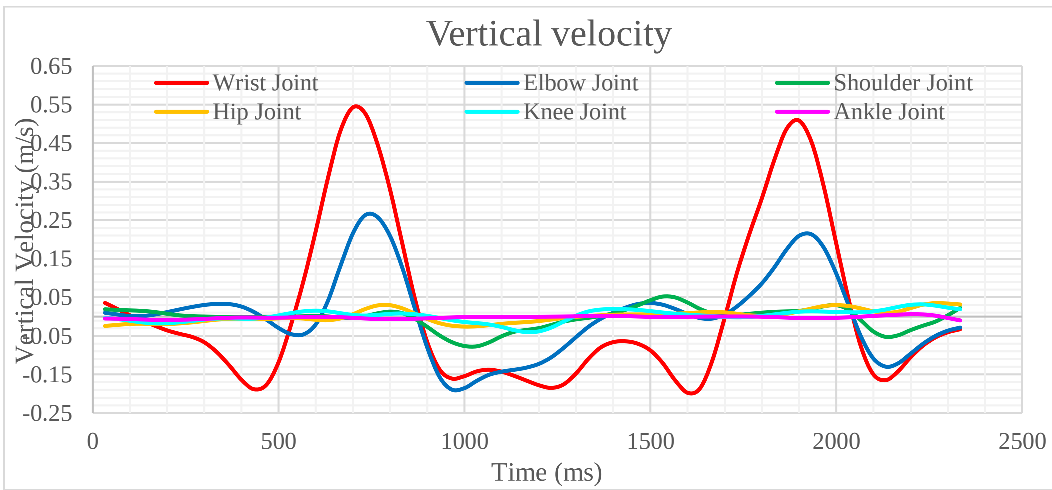

Figure 5-62 Vertical velocity of joint of person 11

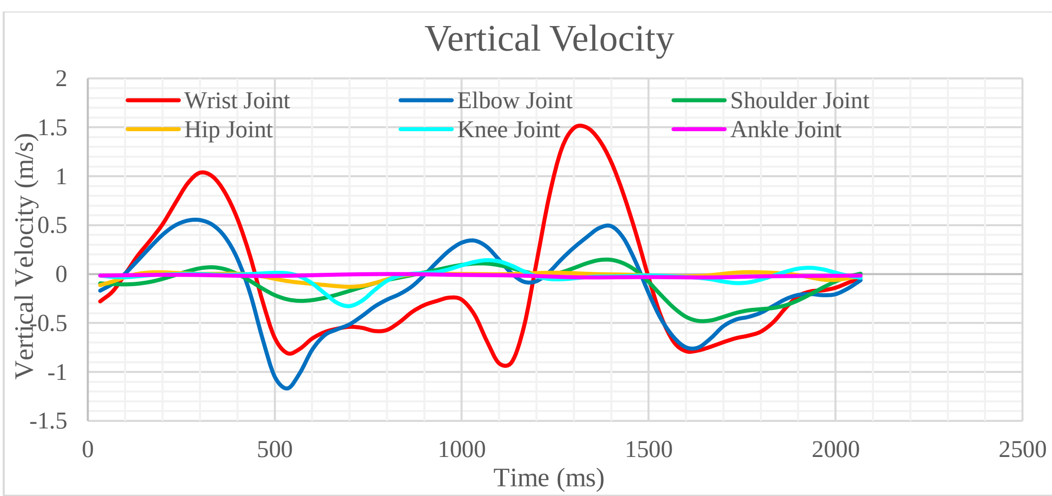

Figure 5-63 Vertical velocity of joint of person 12

6) Speed:

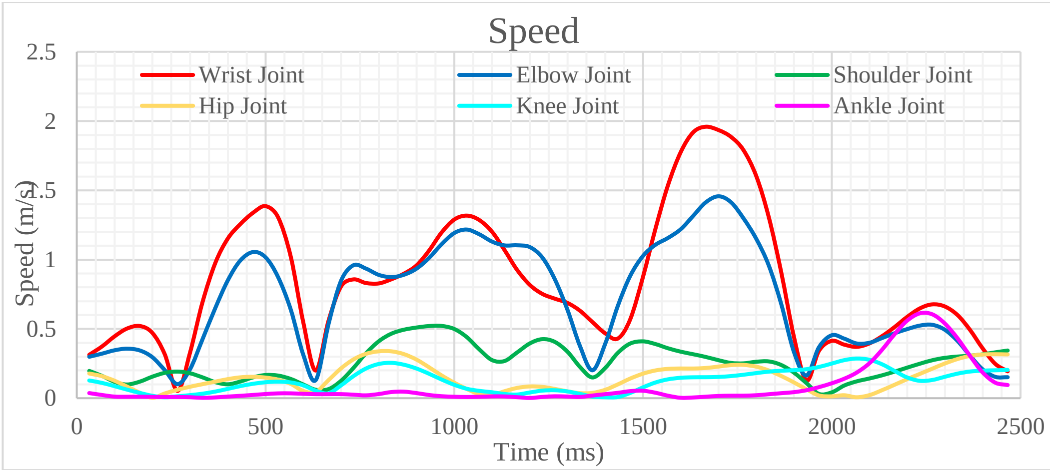

Figure 5-64 Speed of the joint of person 1

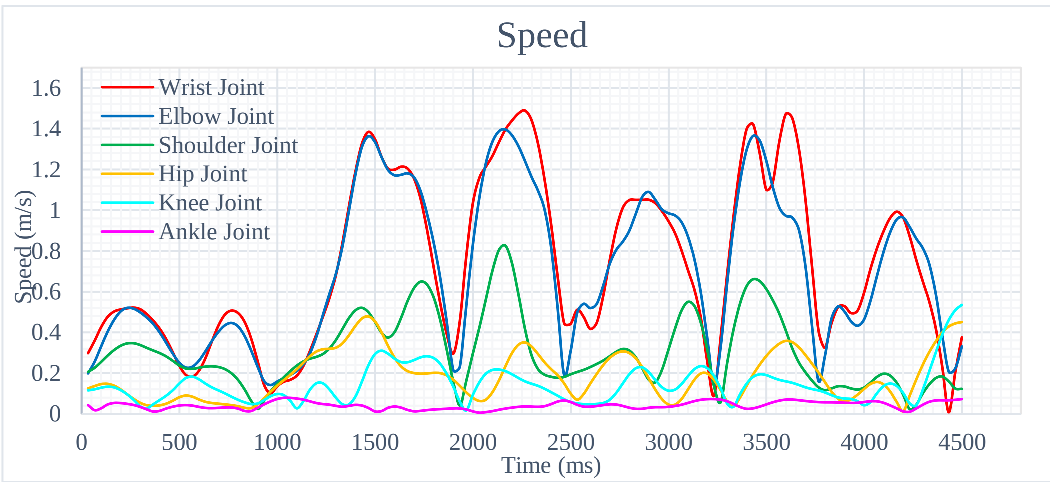

Figure 5-65 Speed of the joint of person 2

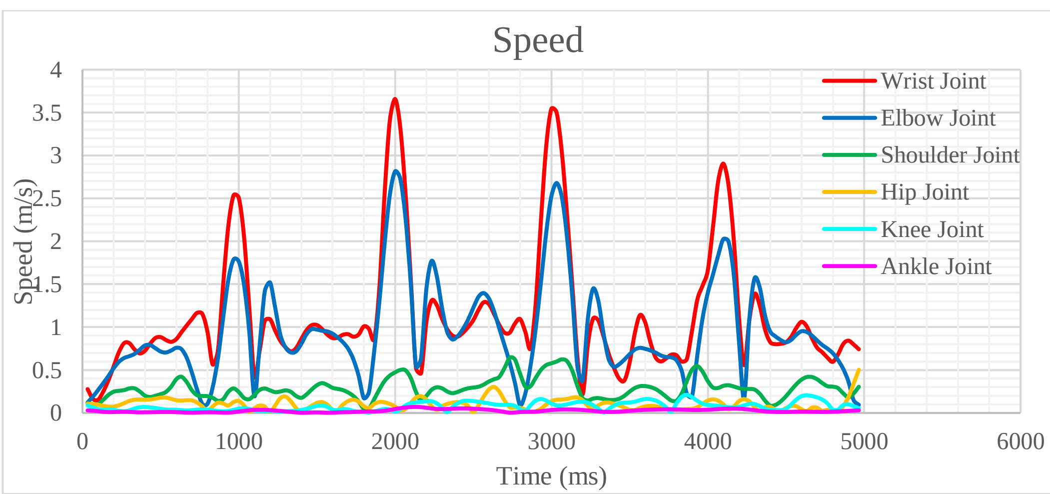

Figure 5-66 Speed of the joint of person 3

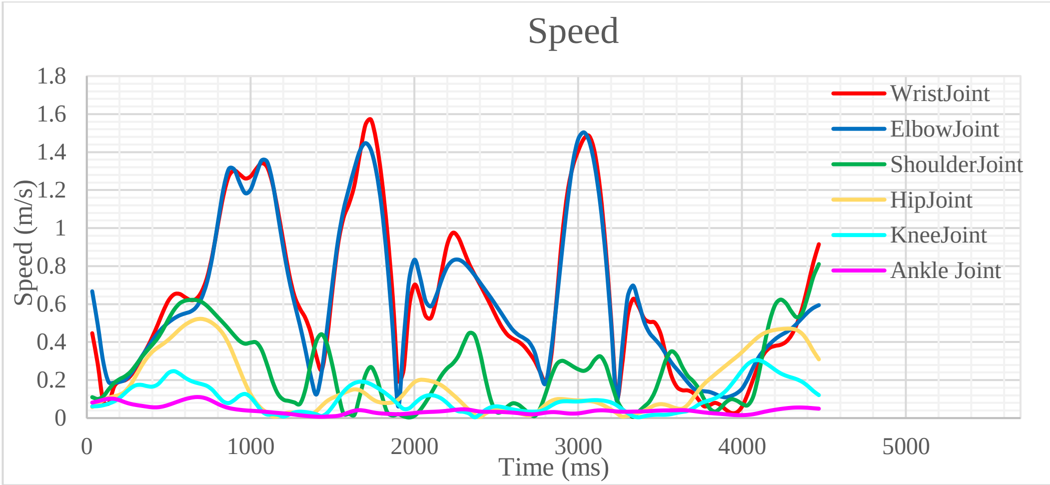

Figure 5-67 Speed of the joint of person 4

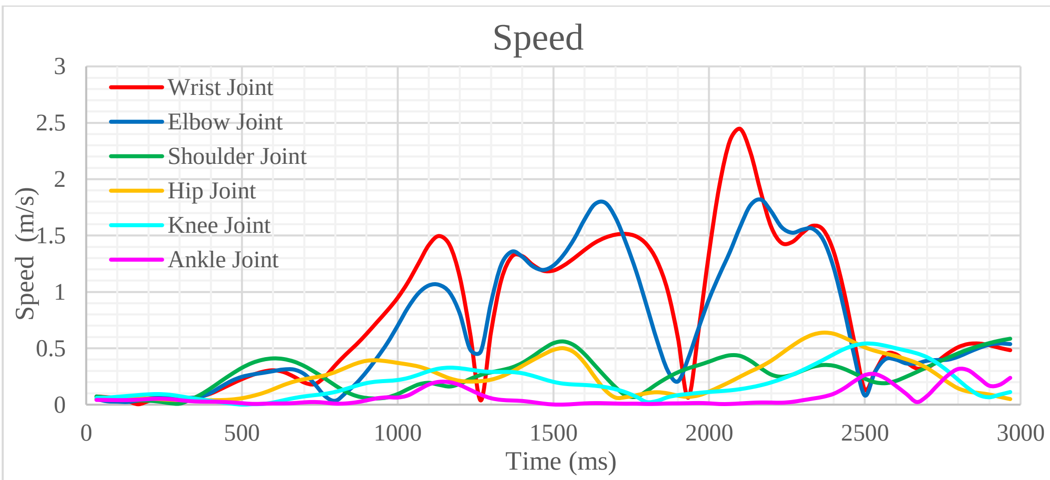

Figure 5-68 Speed of the joint of person 5

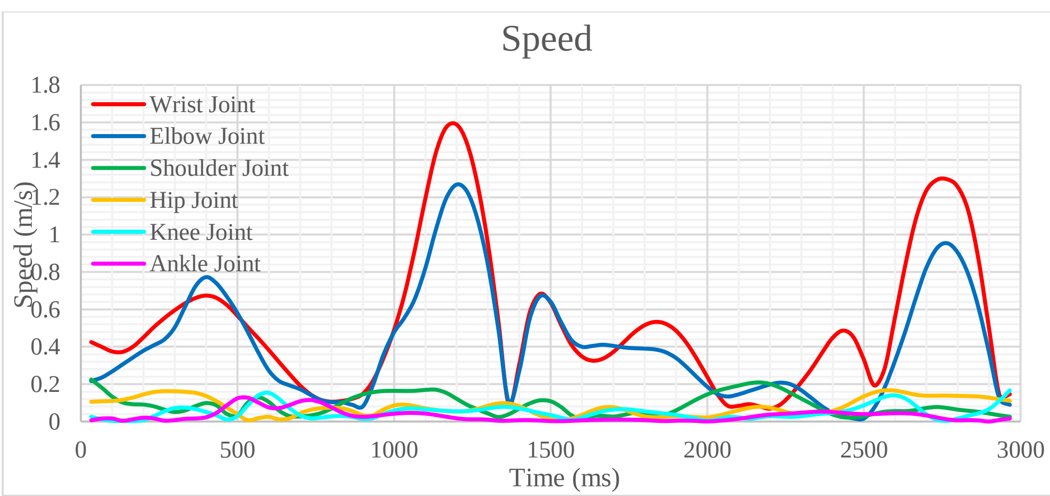

Figure 5-69 Speed of the joint of person 6

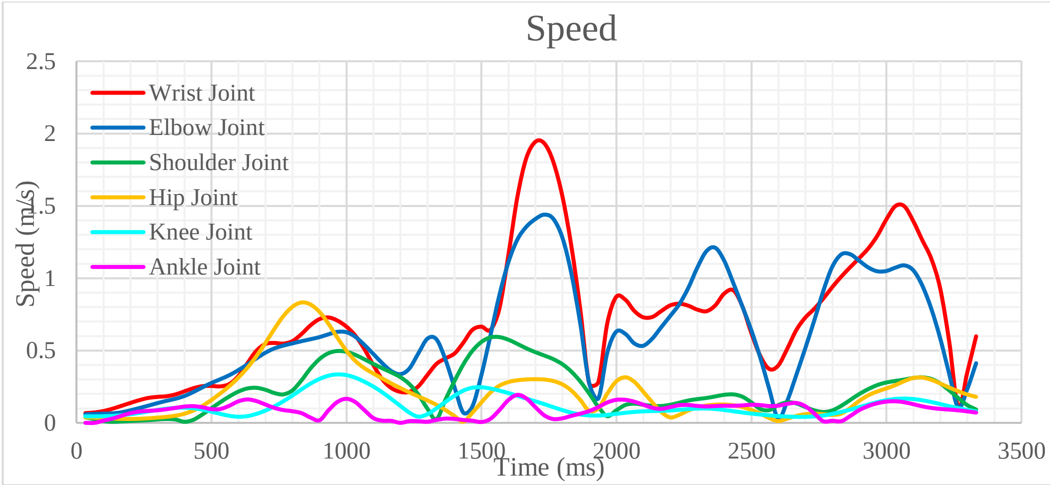

Figure 5-70 Speed of the joint of person 7

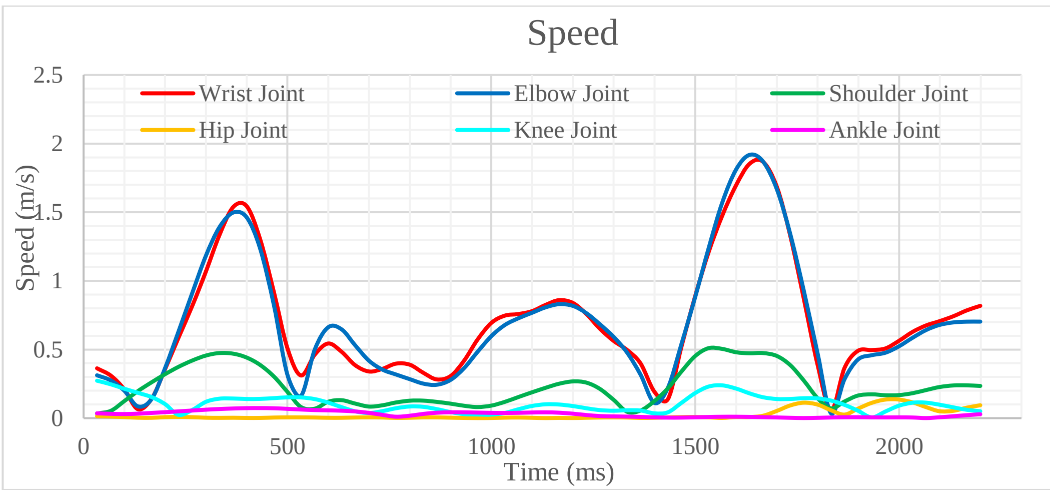

Figure 5-71 Speed of the joint of person 8

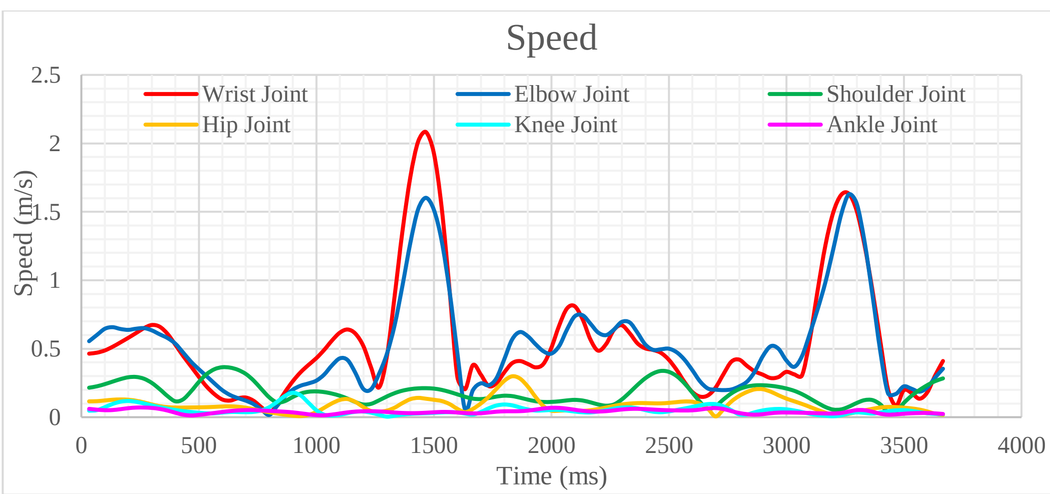

Figure 5-72 Speed of the joint of person 9

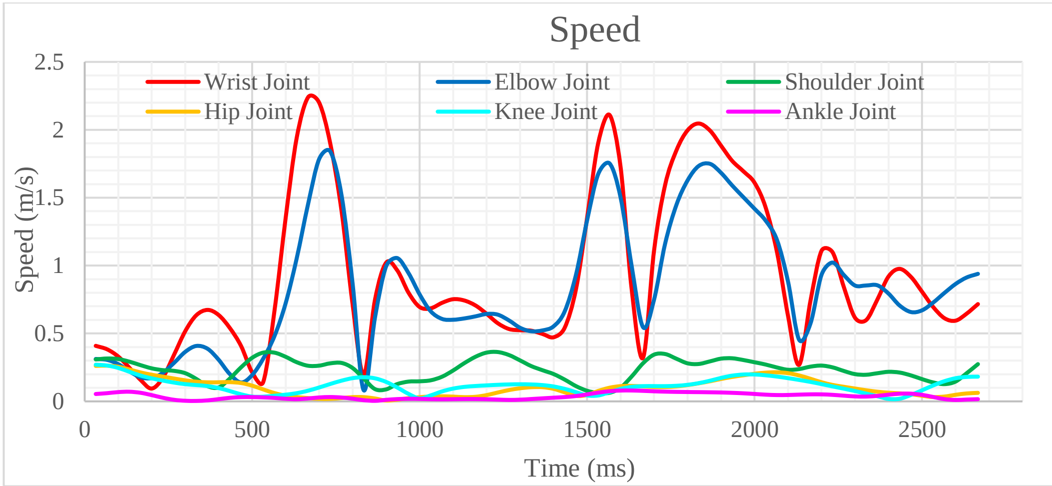

Figure 5-73 Speed of the joint of person 10

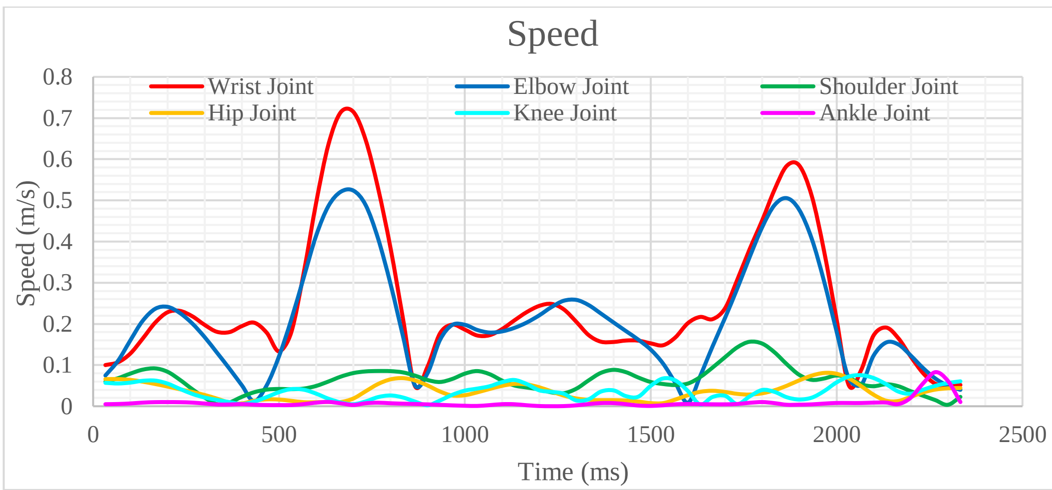

Figure 5-74 Speed of the joint of person 11

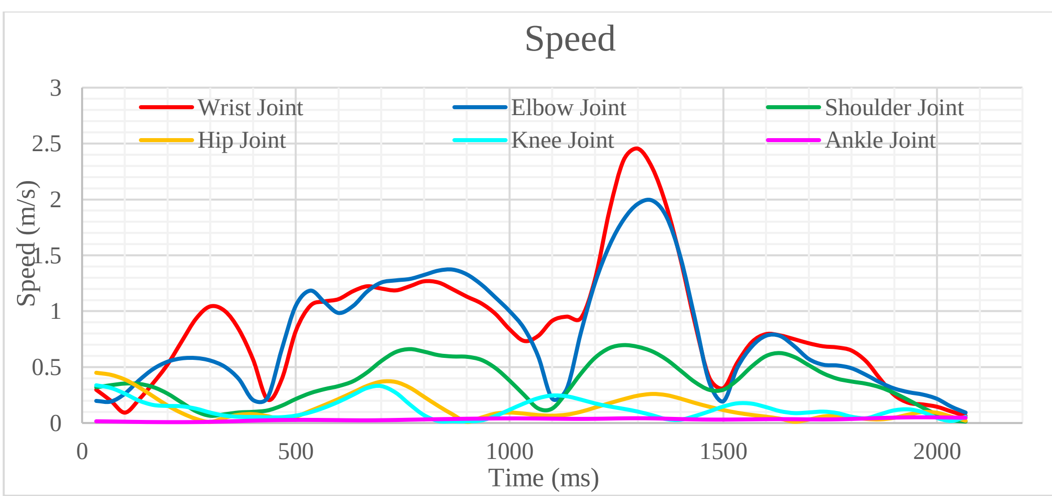

Figure 5-75 Speed of the joint of person 12

7) Angles Vs. Time:

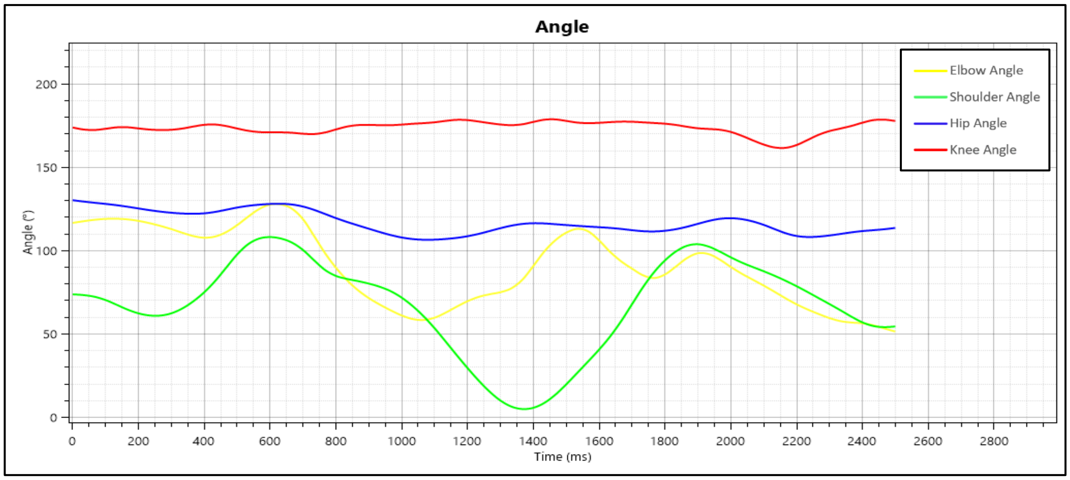

Figure 5-76 Angular displacement of joint of person 1

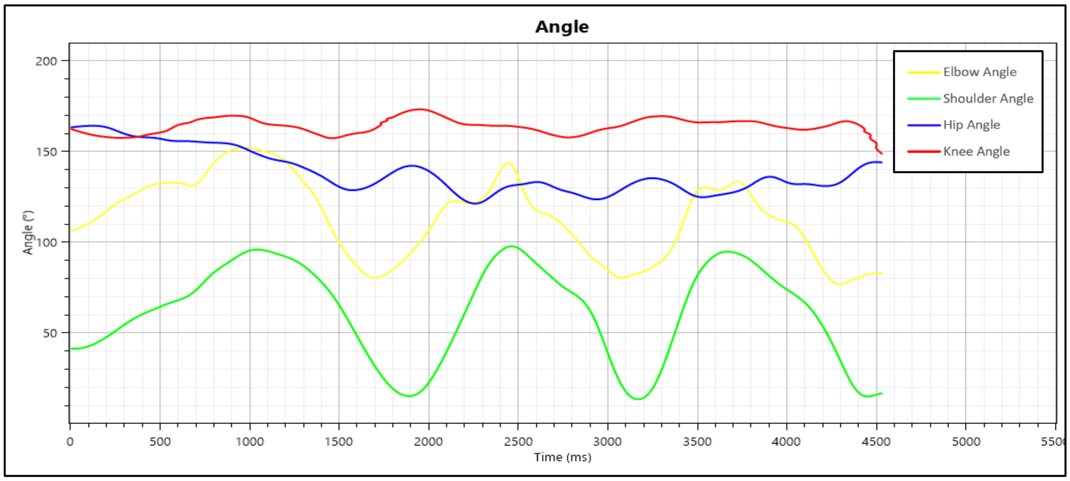

Figure 5-77 Angular displacement of joint of person 2

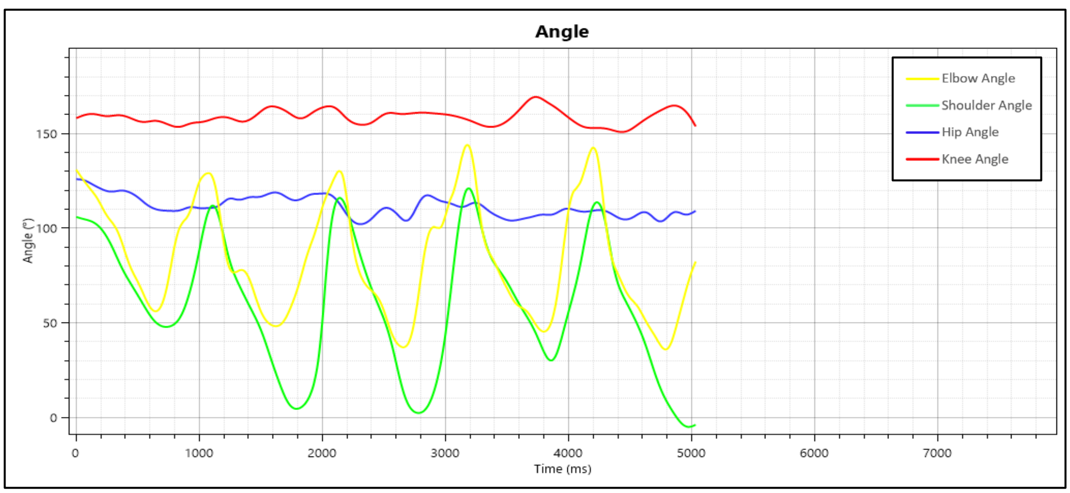

Figure 5-78 Angular displacement of joint of person 3

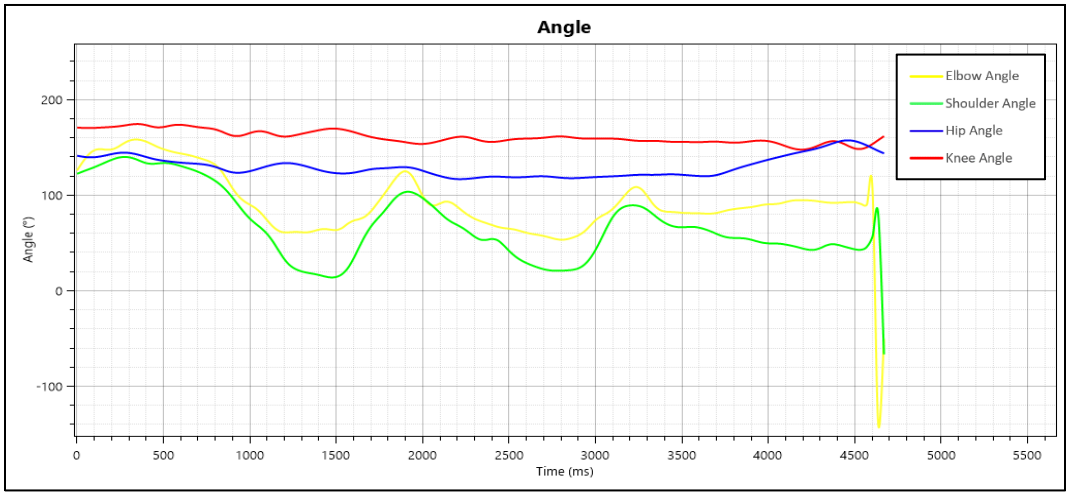

Figure 5-79 Angular displacement of joint of person 4

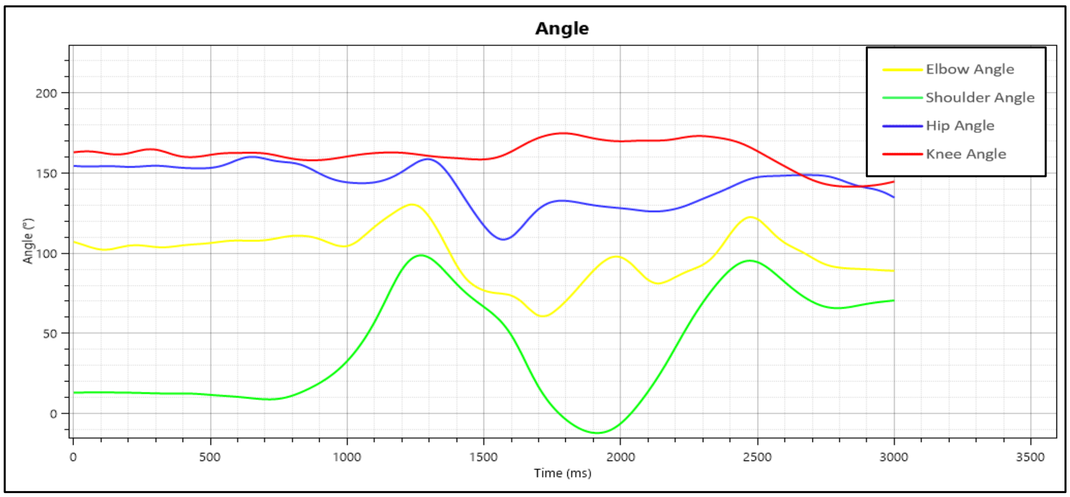

Figure 5-80 Angular displacement of joint of person 5

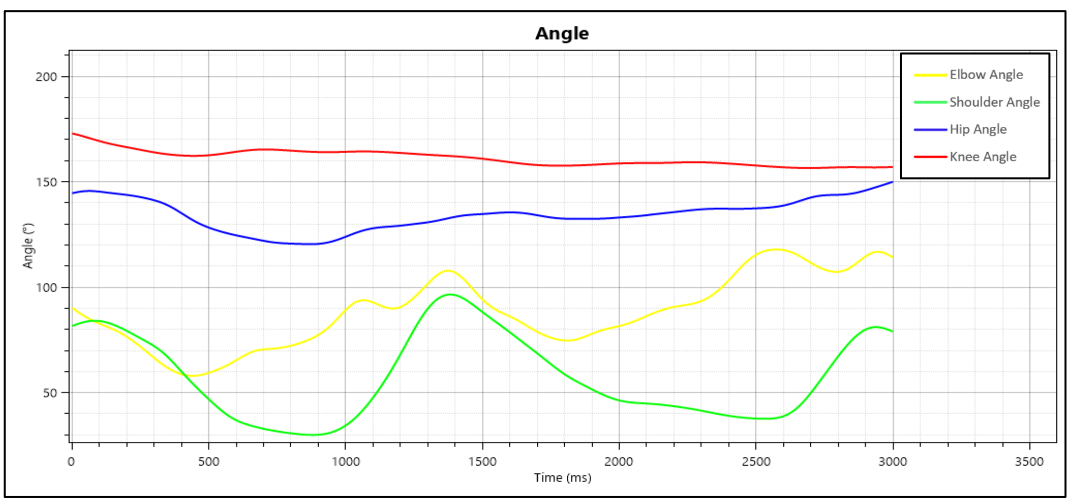

Figure 5-81 Angular displacement of joint of person 6

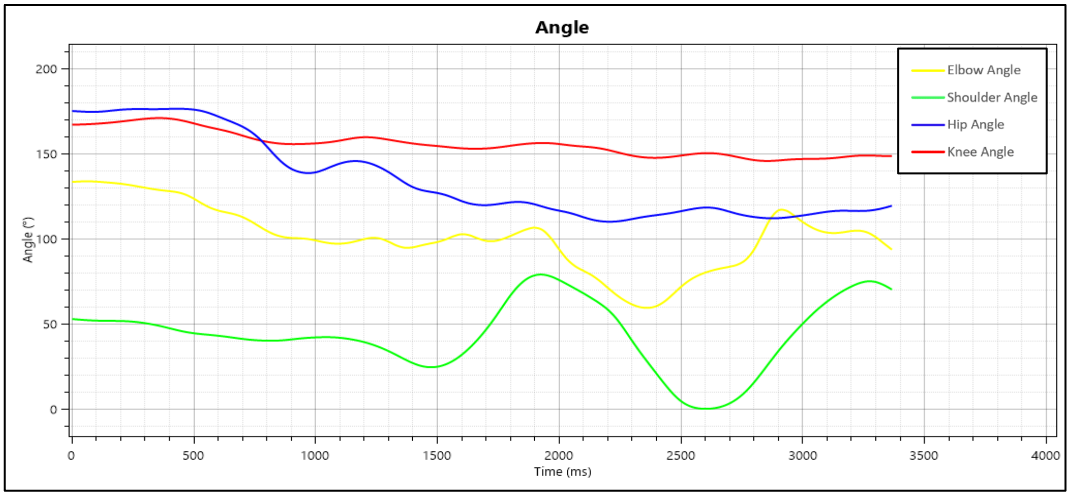

Figure 5-82 Angular displacement of joint of person 7

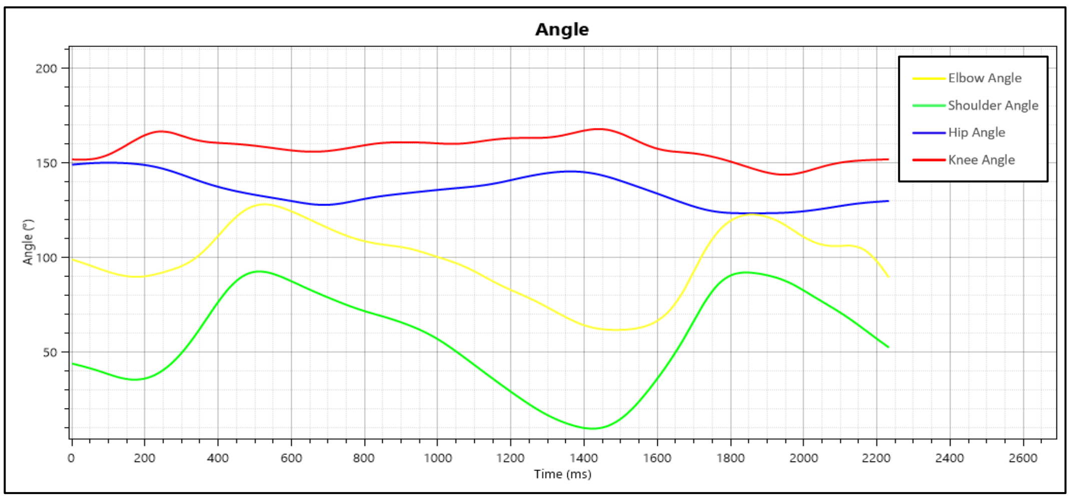

Figure 5-83 Angular displacement of joint of person 8

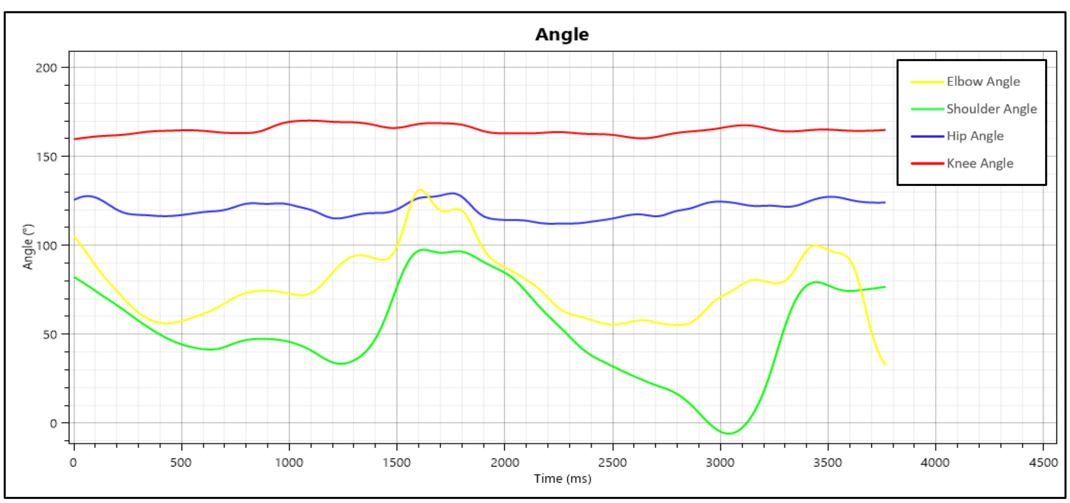

Figure 5-84 Angular displacement of joint of person 9

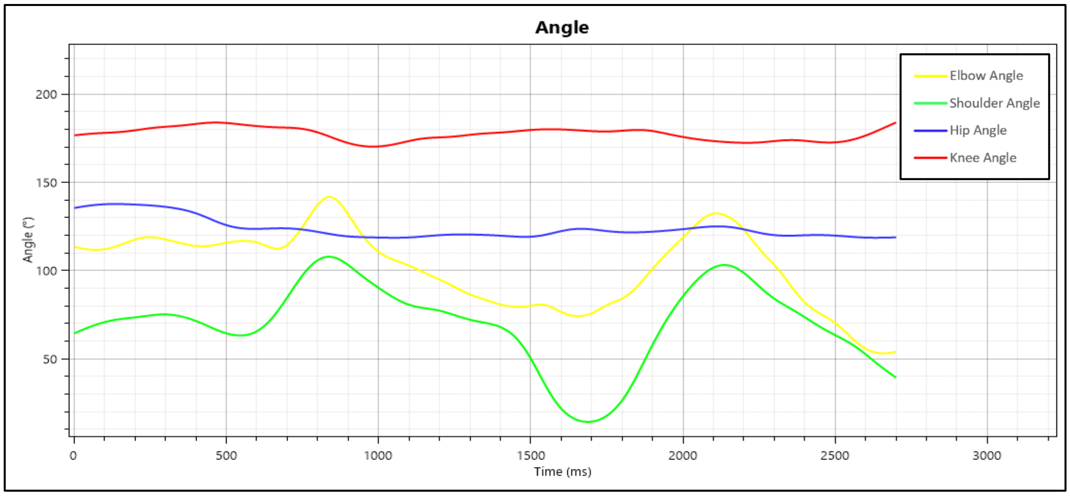

Figure 5-85 Angular displacement of joint of person 10

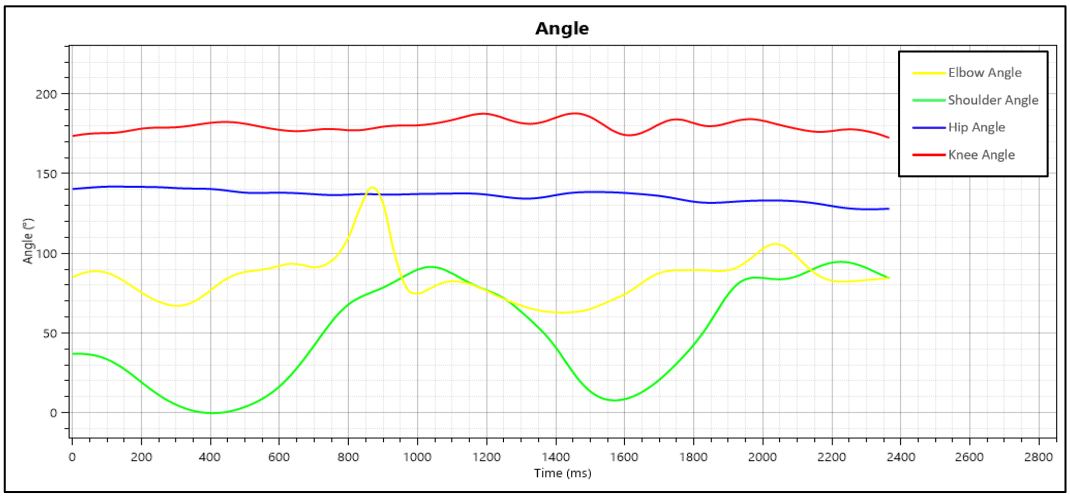

Figure 5-86 Angular displacement of joint of person 11

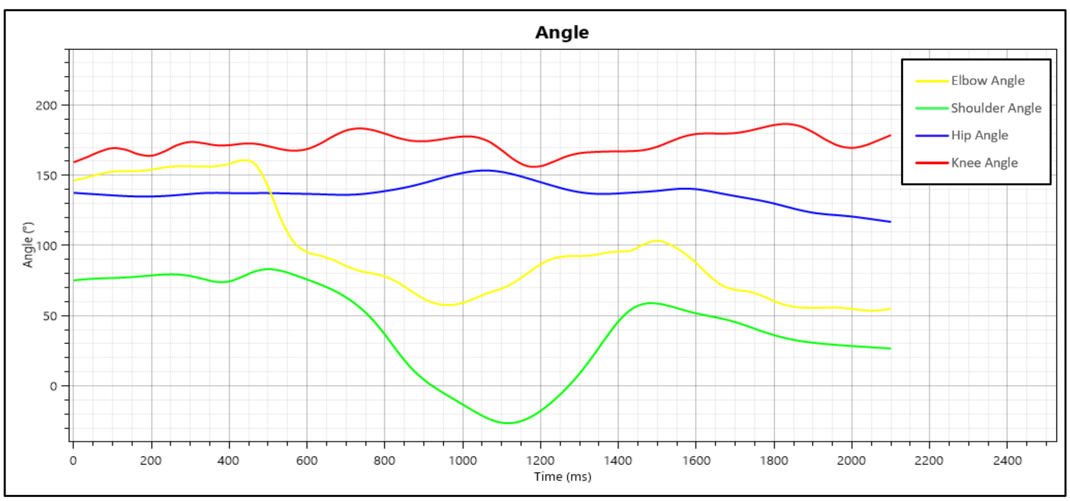

Figure 5-87 Angular displacement of joint of person 12

8) Stick Diagram or Stick Human Figure

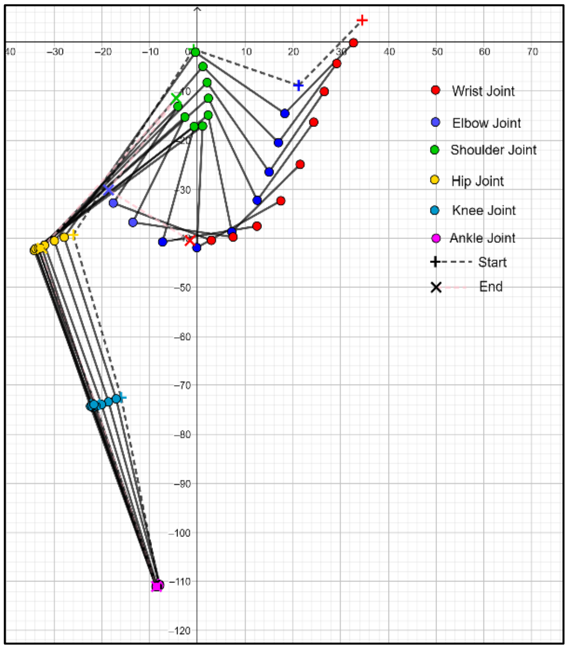

Figure 5-88 Stick diagram of Person 1 from right side

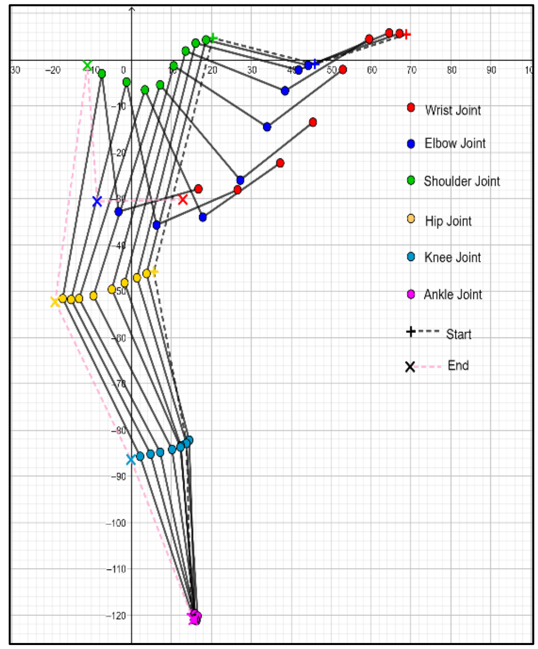

Figure 5-89 Stick diagram of Person 2 from right side

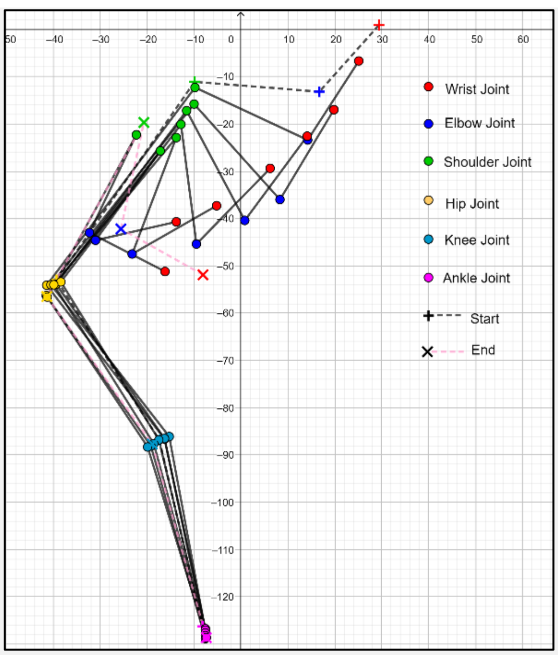

Figure 5-90 Stick diagram of Person 3 from right side

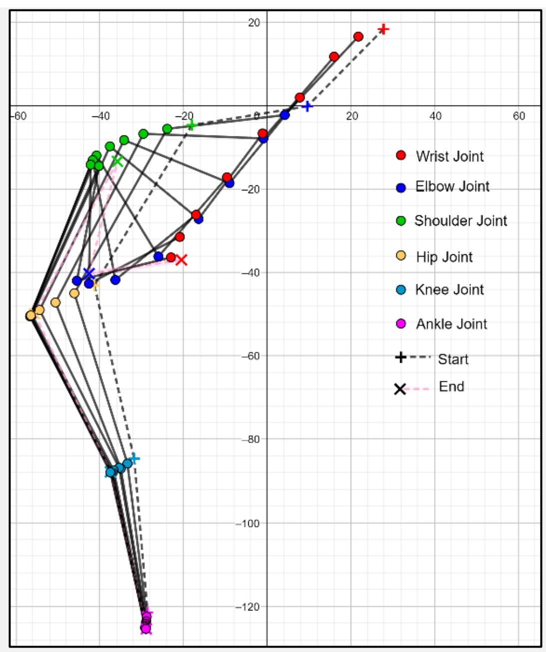

Figure 5-91 Stick diagram of Person 4 from right side

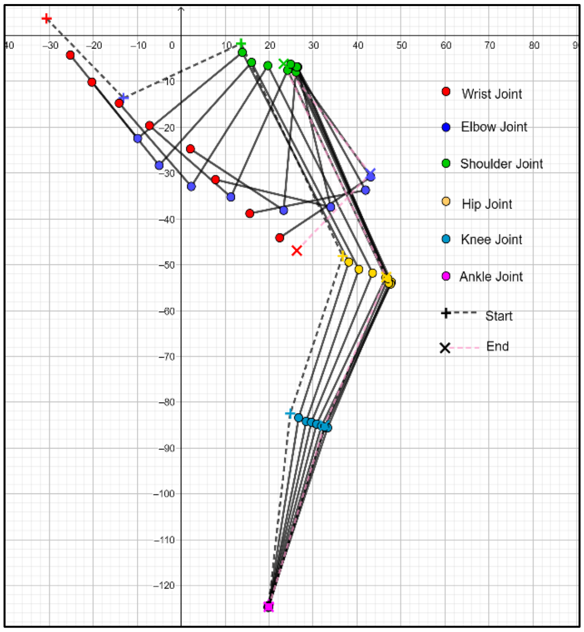

Figure 5-92 Stick diagram of person 5 from left side

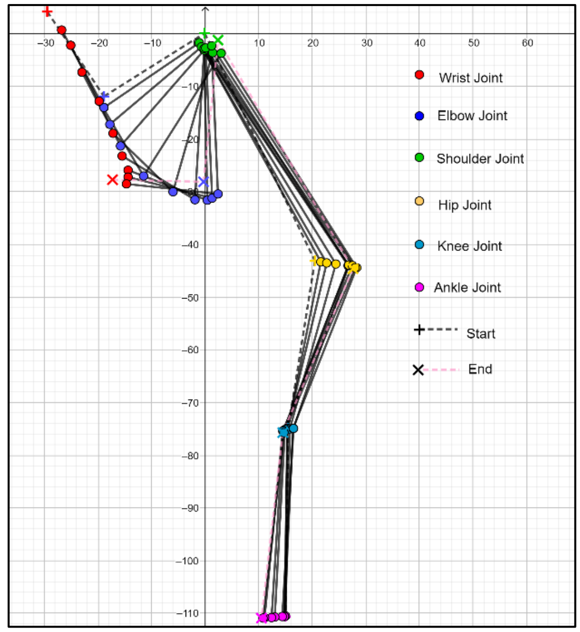

Figure 5-93 Stick diagram of Person 6 from left side

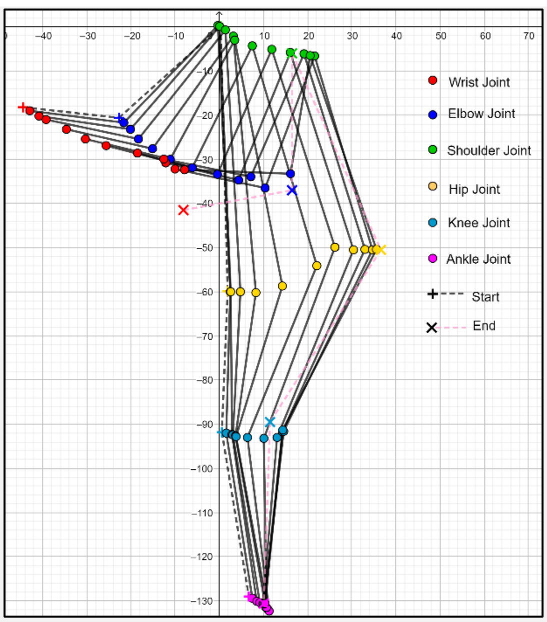

Figure 5-94 Stick diagram of Person 7 from left side

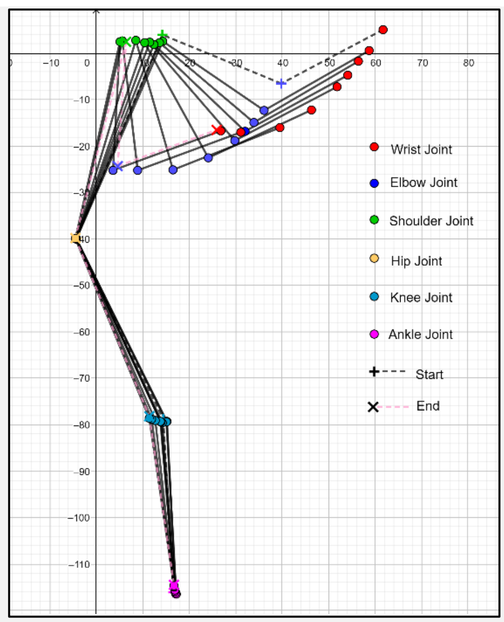

Figure 5-95 Stick diagram of Person 8 from right side

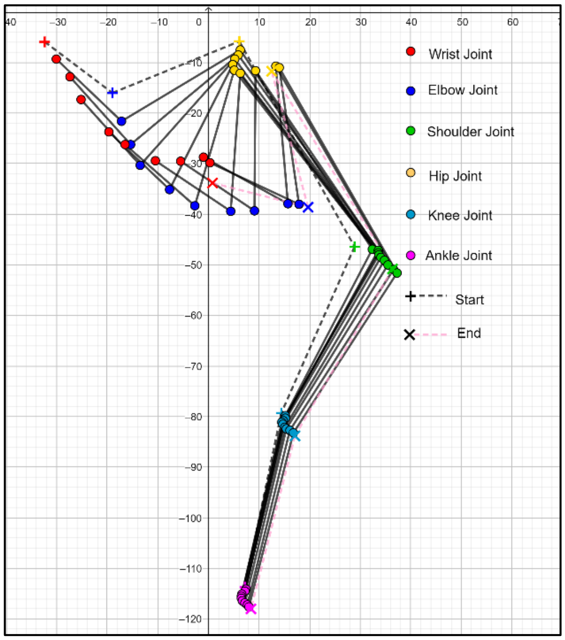

Figure 5-96 Stick diagram of Person 9 from left side

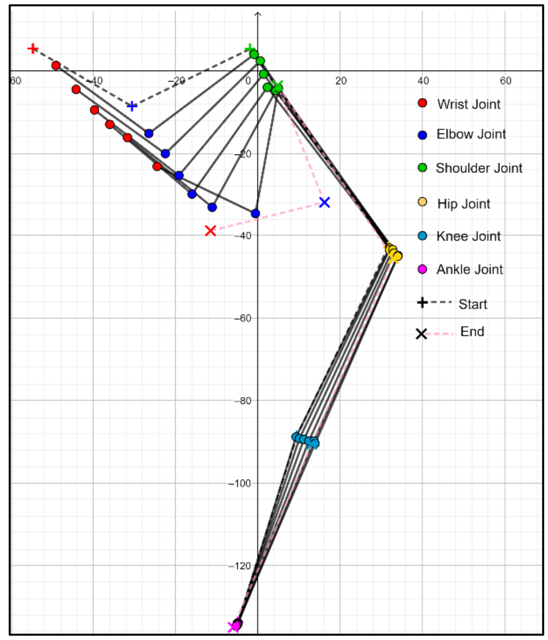

Figure 5-97 Stick diagram of Person 10 from left side

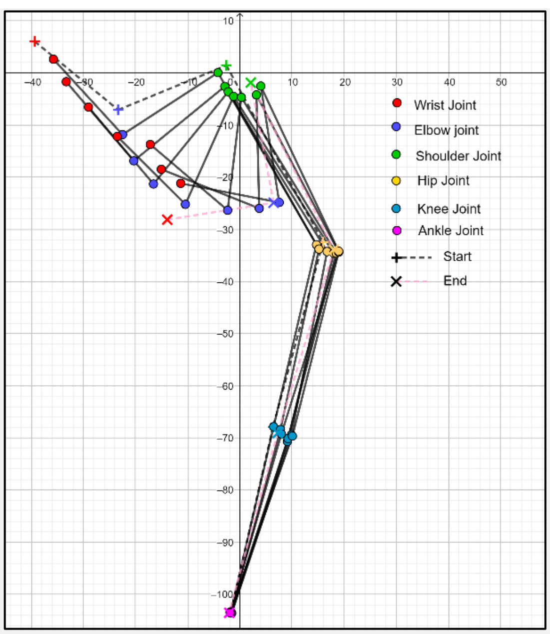

Figure 5-98 Stick diagram of Person 11 from left side

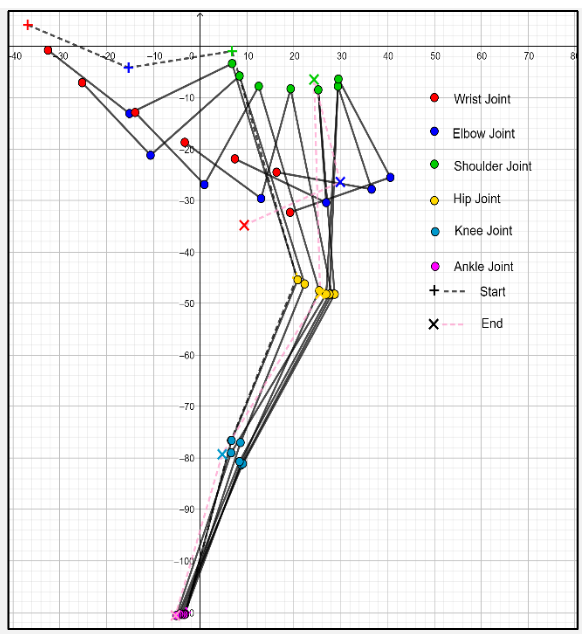

Figure 5-99 Stick diagram of Person 12 from left side

9) Load in different pulley during while water lifting

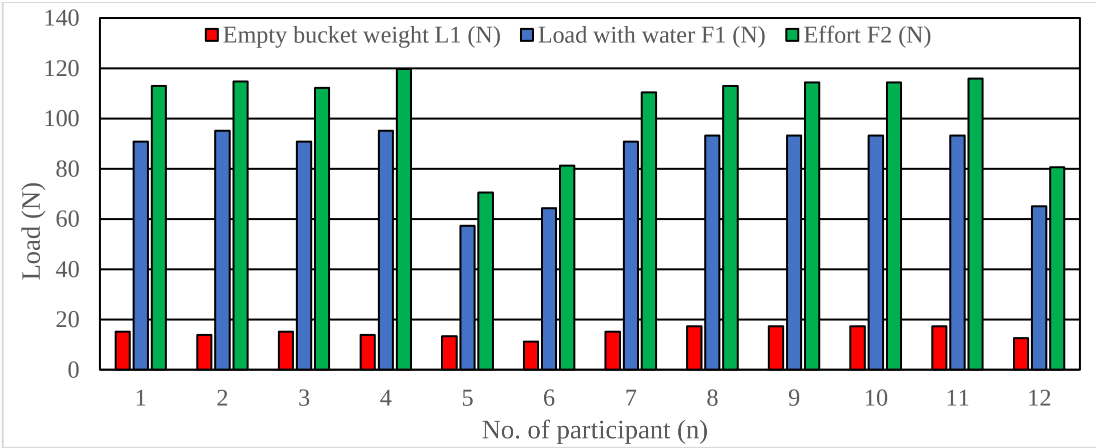

Figure 5-100 Load variations when pulley has coefficient of friction µ=0.084 for different participant

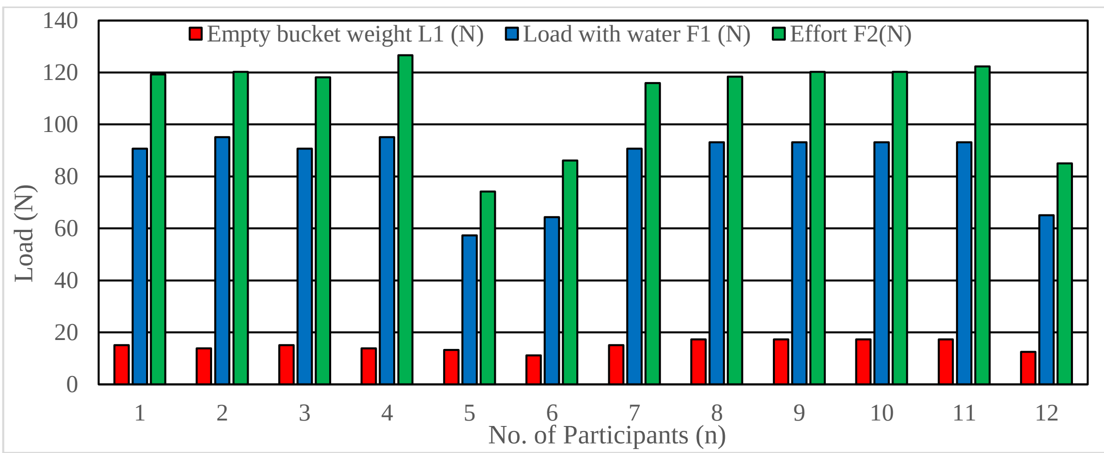

Figure 5-101 Load variations when pulley has coefficient of friction µ=0.105 for different participant

10) F2/F1 vs. ϴ

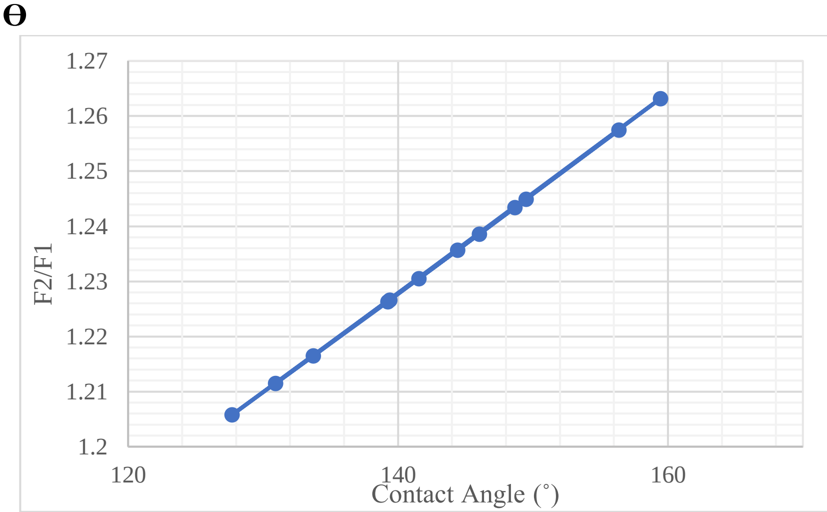

Figure 5-102 Load ratio vs. Contact angle between rope and pulley at µ=0.084

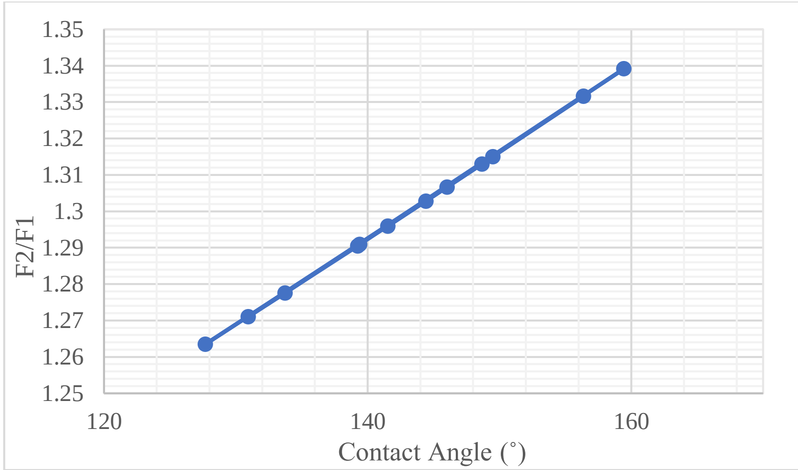

Figure 5-103 Load ratio vs. Contact angle between rope and pulley at μ=0.105

11) Ln(F2/F1) vs. Ɵ

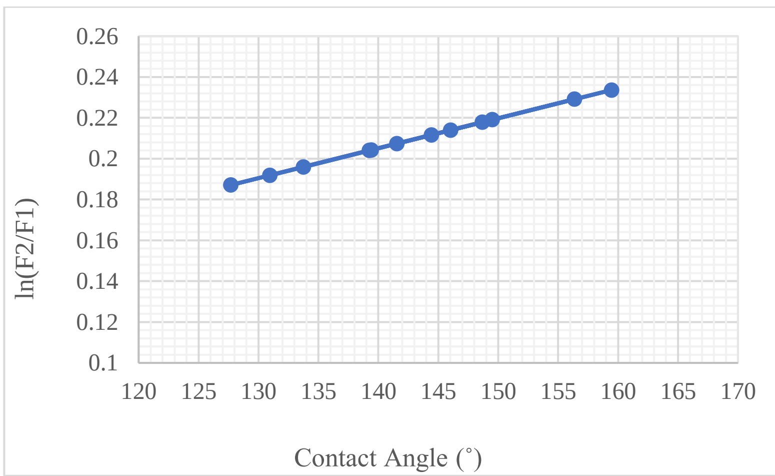

Figure 5-104 Logarithmic distribution of force ratio w. r. t contact angle for μ=0.084

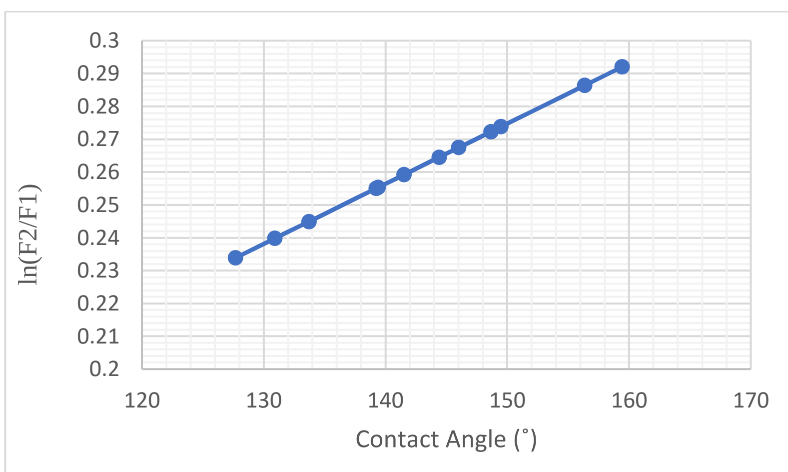

Figure 5-105 Logarithmic distribution of force ratio w. r. t contact angle for μ=0.105

12) Load lifted vs. angles

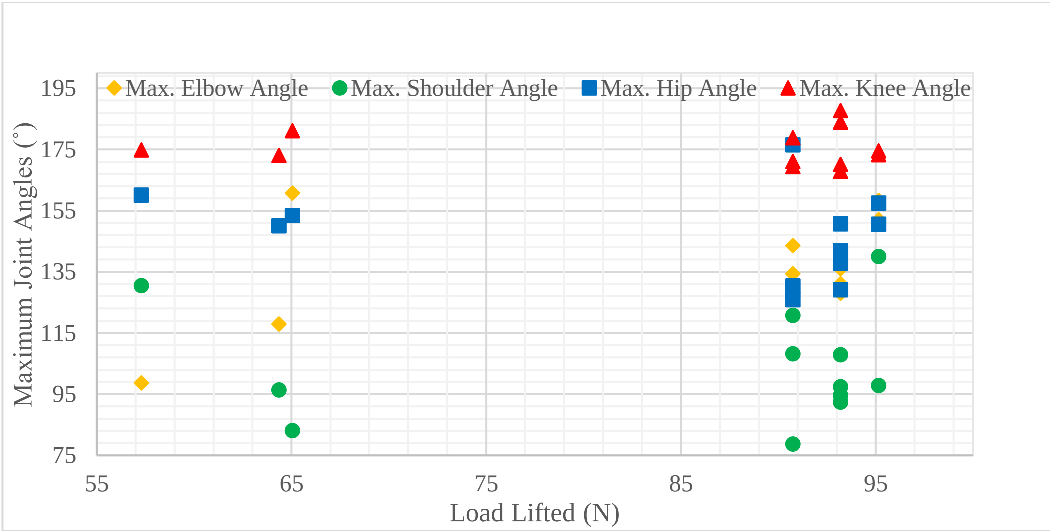

Figure 5-106 Comparison of maximum joint angle for different people

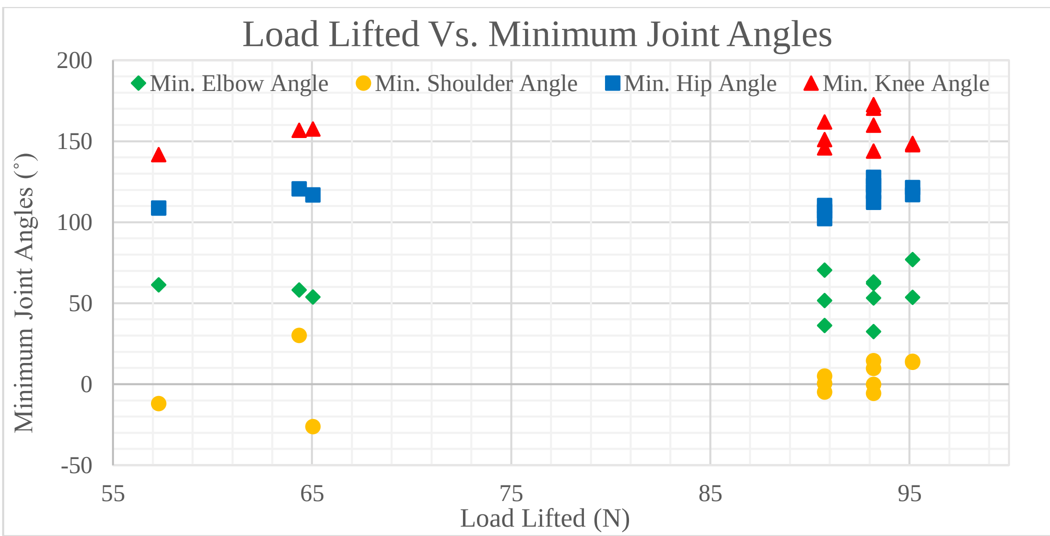

Figure 5-107 Comparison of minimum joint angle for different people

6 DISCUSSIONS

The discussion is made after realizing the results in a questionnaire, observation and human model. If we see the questionnaire, it can be seen, the pain mostly pain is in the lower back or upper back. Mostly pain is occurred and lasts in the back, then neck and hand.

While evaluating, it can be seen that the observation method of ergonomics result is different for each and every person or varying by case to case. It can be either in the angles or in the load or muscle score or any other different area. So, the discussion is done as per the review of the research results that has been drawn.

If we see the exposure level of the final score of RULA, REBA, and ART assessment, the score represents the exposure risk level of musculoskeletal and therefore, we can go for a solution that shows how to lower the score.

For RULA, 12 participants were observed by videos of actions and concluded in RULA score. It has been seen that seven out of twelve participants show a score of ‘7’ which interprets the level of exposure as “investigate and implement change”. Out of remaining, four participants got ‘5 or 6’ as outcomes which shows “further investigation, change soon”. And only one person score ‘4’ which represents “further investigation, change may be needed”.

People with score ‘7’ has the very high risk in musculoskeletal disorder or disorder in posture. So, for finding a solution, we can go for making low score somehow. So, we have to observe the places or analyse the area where the score is high in body postures. In somehow if we see high score in the upper arm analysis, we have to analyse the angles. For low score, we have to maintain the score at or within 45-90˚. But if it is kept under 20-45˚. Then it will be more helpful. Because for adjustment in leaning -1 is added which lower down the score for 1 unit. So, in the overall score of upper arm analysis, it can be ‘1’ or ‘2’. And getting these angles can be found by the distance and height of the pulley and the person standing.

A person with high angle in lower arm should be kept low such as between 60-100˚. It also should be kept in mind that the flexion and extension should be happen in the same amount.

Because if it happened, then the average angle of lower arm can be much lower or can be neutralized what we expect. For wrist position, the wrist should be in neutral position during pulling without bending too much and deviating. If it gets deviated from mid-range then the result score on wrist can be higher because of the addition of score which should be avoided. Since wrist twist is also focused, we see that without knowing, some participants twisted their wrist to get the force to pull up the water. So, knowing unknowingly wrist twist is there. Now, if the force or load in concentrated on hand can bring lower, it is an approach to score lower. The load can be static, shock or repeated but should lower than 5kg.For neck score, the neck angle should be between 0-20˚, otherwise the neck score will be high. For trunk, angle should be kept as much as neutral or cannot go beyond 20. For leg, both legs should be balanced equally to reduce stress and imbalance and score. If we maintain to lower score for neck, trunk, leg then the resultant score can be low. It will be better if the muscle score can be zero which means if there is some recovery period of times and if the posture is static then it may create hazards in musculoskeletal disorder.

Unlike RULA assessment, *REBA assessment* is also an additional score analysis, ergonomics observation method. In the REBA assessment it has been seen that, out of 12 people, 2 people got score of 8 that has exposure level of ‘high risk, investigate and implement change’, 9 people got score of 4 to 7 which interprets as ‘medium risk, further investigation, change soon’ and only one participant scores 3 which interprets ‘lower risk, changes may or may not be needed’.

The different of RULA and REBA in scoring is in such a way in REBA, most of the participants fall under medium risk. And the score is different because of the steps of evaluation but same condition is applied. The condition is as much as lower the score. To lower the score, some assumptions were followed.

i) For neck position, the angles should be kept as much as low, for example 0-20. If somehow score gets increased, then it should be adjusted by trunk, leg score.

ii) For trunk, it will be better if the trunk stays in neutral or if it flexion, the angle should be kept under the range of 0-20 for lower score.

iii) For leg, they should be balanced equally and knee angle should be low as much as possible (<30˚).

If these three (neck, trunk, legs) are kept low score that the resultant score of them (Table A) will be low.

i) For the upper arm position, the angle should be kept much lower within 90˚, therefore it gets adjusted with -1 by leaning.

ii) For lower arm, the angle should be within 60-100˚.

iii) For wrist position, REBA assessment doesn't have the same steps as RULA. Here wrist is considered if twisted or not but always be considered in neutral.

By lower these scores, it can be got resultant value (Table B) of score in 1 or 2 which is lower, so it can use for natural rehabilitation mode. The force/ load score, can be lower if the load is lower than less than 22 lbs (10kg). For coupling, it should be kept maintain in between 0 to 1 to get a reduction in score using good grip and fair grip. Activity score should be tried to neglect if possible. If activity score is lower or avoid then the resultant final REBA score can be lower.

For ART assessment, it evaluated that, if somehow force, awkward postures and duration of works become low and higher the break as recovery time then, it will be helpful to lower the score even though score will be under medium level of exposure level. Out of 12 people, 1 person shows high level of risk and all other fall into medium level of risk.

If we considered the motion in human models, it has seen from the stick diagram and related graphical representation that the posture is mainly moving with non-uniform velocity. Most of the people moves their hands (wrist & elbow joint) with higher displacement where ankle joint rarely moves. Analysis all the participant, which is common for all of them is the displacement of wrist and elbow joint.

From the stick model, it can be seen that the human body joint in working cycle is divided in many phases. And each joint is moving in a different pattern. As wrist is coming down, the elbow too is coming down, shoulder joint is moving in a particular projection, the hip is seeming to be moving in backward. Keeping the ankle in same position, the knee seems to be moving. So that is because of the swinging of hip. The gap in the wrist joint and elbow joint is seems to be closer at first but as it gets down the gap becomes larger and at the end it become closer again. The horizontal position for wrist and elbow joint moves with much variation than any other joint. Whereas, it has seen that the horizontal position for shoulder, hip and knee is moving with small variation but the ankle joint is nearly same during the work. Same goes for vertical position too, ankle is nearly stable but other joint is moving with a variation. If we consider the total distance, for every participant it can be seen that the maximum distance covered by the wrist joint and the least distance is covered by ankle joint. For horizontal velocity and vertical velocity, the velocity at wrist and elbow joint shows rapid changes during the movement. At the start and end of the cycle, the velocity at wrist and elbow joint is comparatively low than intermediated position. But for, shoulder, hip and knee joint these changes in horizontal velocity is little compare to wrist and elbow joint. And the velocity at ankle joint barely changes throughout the action. If we see the speed at the joint, we can see that mostly, the rapid changes are seen in the wrist and elbow joint. The low rapid changes in shoulder, hip, knee joint but ankle joint is very much lower and nearly steady.

For the angular displacement, it can be seen that inside angle of elbow and shoulder has the most changes. As much as it has rapid increasing, same way it has rapid decreasing throughout the whole cycle. But for hip and knee angle these changes are very much within a range.

For the load variation, it becomes clear that the effort or the load in hand while pulling becomes greater than the original load (bucket with water) because of the coefficient of friction. The experiment was done in two pulleys. The pulley has higher coefficient of friction shows higher effort (load in hand). To lower the effort than it is, the contact angle should be kept lower if lubrication is there. Comparing the load lifted and effort with contact angle in normal value shows as much as the contact angle is there, the load is higher for both the pulley. If we see the load variation of empty bucket, filled bucket and the load fall on hand, it shown that the load on hand (effort) is always higher than the actual load. Therefore, we can say that there is a frictional load which makes some power loss in the body. We have seen that, as much as the contact angle of rope is higher, the frictional load is higher and the power loss of the human is higher. It is mainly due to increase of contact area.

Even if the load is same for few people, it has seen that the joint angles displacement with its maximum and minimum value is different for person to person. Even if the load is same for some participants, the linear displacement of the joint is also different person to person.

As overview, it is evaluated that the problem cannot go away totally but can be maintained and lower the affect by accepting some terms and condition.

7 CONCLUSIONS

This study highlights the problem related to musculoskeletal disorder during water collection in one of the villages of Jhargram, West Bengal, India. The disorder interferes with the people's ability and impact during household activity of housewives. The study was done and observed to carry out the problems having symptoms of musculoskeletal disorders and its level of risk exposure. The health if effected by chronic disorder and because of their daily life, the work environment is hazardous. Water collecting from well is basically done by female of the villages for any kind of work in home. The work is investigated by some methods on the basis of work, the relationship of the pattern behaviour and effectiveness on duration.

The main reason of this thesis is to finding the joint displacement by linear and angular motion, velocity as per different pattern so that it can be find out which joint has the most effect.

For this experiment, we had to survey, capture video had small research for knowledge and then carrying out the whole research as per need. Therefore, as per experiment, it has been found out that mostly wrist joint and elbow joint were moving. But ankle, knee, hip joint was positioned static, because of which these got force higher than the moving joint. So, pain in the shoulder, neck, back, knee is higher in the survey of 24hours, 7days, 30days by using standard questionnaire. By using observation method of ergonomics, it has found out that because of the abnormal angle, it leads to chronic pain and numbness.

The effort is higher in hand because of the rope contact angle in pulley which is directly proportion to coefficient of friction in the pulley makes losses of power in pulling.

Even though there is small study size and lacks power, but still highlighted the impact on health. But more study can bring a confirmation on the health issue. Still need research where it can highlight the effect on neck and back by water carrying. It can confront how such pain impact on lives.

7.1 Recommendation

1. Workplace design: keeping the pulley lubricated, so that the load on the hand (effort) can be low.
2. Implement a workshop program to aware of the factors concerning related to musculoskeletal disorders.
3. People should be aware and motivated to adapt techniques that are preferable.
4. Should went to doctor whenever possible without waiting for critical outcomes.
5. The load should be kept low or lower than 5 kg.
6. Rest should be taken properly after the work.
7. Showing physical fitness exercise importance.
8. For older people, it is better if they can avoid. Other than if they must work, then should kept in mind the proper posture and lower load only to be work for.

7.2 Future scope

As it was mentioned in the review paper, there are many areas where research gapes are there. And future research can be gone through by these areas –

1. The topic needs to be investigated is the distance effects on the musculoskeletal disorder during carrying the load, and how the effort is divided in the joint of body.
2. The height and distance from person to pulley, how it changes scores of the ergonomics method.
3. If a person has illness, then how these works affect them.
4. An investigation on the comparison of the load and musculoskeletal disorders between women, children and men.
5. An investigation of the walking posture between people from town and villages who took the load of house chores.

The above scope for research can be useful for the better understanding of human critical posture, biomechanical principle, a simulation of muscle tension. Therefore, it can be use in the artificially intelligence to change and bring a better point of view.

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APPENDIX I

Standard Musculoskeletal Disorders Questionnaire

Musculoskeletal Discomfort Form (Based on the Nordic Questionnaire (Kourinka et al. 1987))

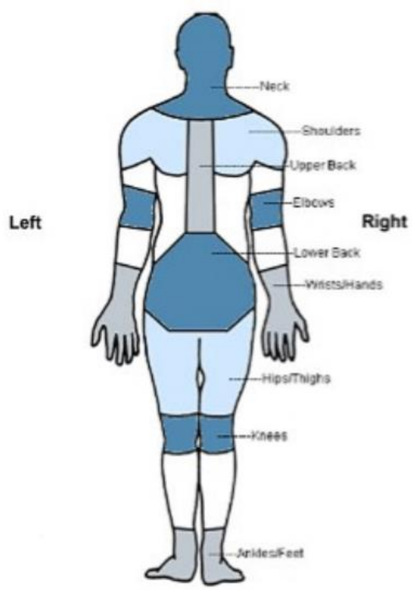
Employee ID:____________________

Job/Position: ____________________ Gender: M F Age: ______ Height: ____ ft.____ in. Weight: __________

How long have you been doing this job? ___years ___ months How many hours do you work each week? _____

How to answer the questionnaire:

Picture: In this picture you can see the approximate position of the parts of the body referred to in the table. Limits are not sharply defined, and certain parts overlap. You should decide for yourself in which part you have or have had your trouble (if any).



Back View

Table: Please answer by putting an "X" in the appropriate box - one "X" for each question. You may be in doubt as to how to answer, but please do your best anyway. Note that column 1 of the questionnaire is to be answered even if you have never had trouble in any part of your body; columns 2 and 3 are to be answered if you answered yes in column 1.

To be answered by everyone		To be answered by those who have had trouble			
Have you at any time during **the last 12 months** had trouble (ache, pain, discomfort, numbness) in:		Have you at any time during the **last 12 months been prevented from doing your normal work** (at home or away from home) because of the trouble?		Have you had trouble at any time during **the last 7 days?**	
Neck ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Shoulders ☐ No	☐ Yes, right shoulder ☐ Yes, left shoulder ☐ Yes, both shoulders	☐ No	☐ Yes	☐ No	☐ Yes
Elbows ☐ No	☐ Yes, right elbow ☐ Yes, left elbow ☐ Yes, both elbows	☐ No	☐ Yes	☐ No	☐ Yes
Wrists/Hands ☐ No	☐ Yes, right wrist/hand ☐ Yes, left wrist/hand ☐ Yes, both wrists/hands	☐ No	☐ Yes	☐ No	☐ Yes
Upper Back ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
Lower Back (small of back) ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
One or Both Hips/Thighs ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
One or Both Knees ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes
One or Both Ankles/Feet ☐ No	☐ Yes	☐ No	☐ Yes	☐ No	☐ Yes

(Interview questions and participant’s answers)

APPENDIX II

Q1. Do you have any other source of collecting water?

Ans- No.

Q2. From when Did you starts collecting water?

Ans- When, we were young. I have no vivid memory, but as much as I can remember, I was barely 9 years old. We used to help our mother, I saw her going fetching water and I used to follow her.

Q3. Where you forced to collect water?

Ans- Forced? No, never. Yes, sometimes, we may not like it. But still, we have to go and collect water because otherwise there’s no option.

Q4. How many times do you collect it? Can you give me a daily routine of your working time?

Ans- Reply from housewives- “we have no idea how many times we collect water. But as you are asking for our routine, then we wake up at 5.30 a.m. After waking up, we go and collect water at least 25 litres for cleaning our face, brushed and related issue then, again for breakfast we collect water at least 20litere. Then, we either started to open shop within 8am. Or we started to clean house. If water is needed for shops, then we need to collect at least 50litre and continue work. Otherwise, we go to ground fro work. When we came back it almost will be afternoon like 4 p.m. Then, again collect water for bath and cleaning all the belonging cloths. While doing so, we collect water nearly 30litres for use it the whole night”.

Reply from teenage daughters (age of 14 or more)- “yes, we also help our mothers for collecting water. Some families don’t have working mother, some of us has mother who are in bed. We cannot look after them very wisely. So, we help our family by doing all the house chores. We may not work hard as our mother but not to create a hazardous in family, we cook and collect water. Water collecting is not easy but we need to do it even if we are on period. I don’t think, water collecting from well leave us with any problem because we have heard our class teacher and tutor to say that it is a very good exercise”.

Q5. Do you feel any pain during the work? What was your first reaction when first time you pulled out a bucket of water?

Ans- "first time when we tried to pull a bucket of water, we couldn't about to pull it. It was so heavy that our hand was felt like about to torn apart. But still, it took a lot of time to get it. But when we got married, even though there was a lot of pain, still we had to do it. But after kept on doing, it got adjusted. We don't feel that much pain anymore".

Yes. Our hand feels numb. It starts to shake a lot. We cannot grab anything at that time. It hurts a lot.

Q6. Do you go to doctors to get rid of the pain?

Ans- Reply from adults- No. we don't. Because we feel that if we take rest then we will feel better and all the numbness, problems, pain will go away. And we don't go to doctors until and unless it is a life threat.

Reply from teenager – No. because our father and mother said that this pain is nothing. There's nothing happen to us. This pain is maniac or it's our thought.

Q7. How much critical position should get you to get a treat to your doctor?

Ans- (reply from housewives)- most of us has to gone through a certain level of pain which is labour pain while delivering the baby. We think, only that time it is certain that we will to doctors. Even some of us works and collect water in such case that even when we're pregnant.

Q8. Even when you are pregnant? How do you work in your pregnancy?

Ans- We always raised to work for our family, in family. So, whether working inside house doing house chores or fetching water from well. We need to do it by ourselves because there's no one who can do it for you. So, even in our pregnancy, we had to work. Some of us collect water in their 9 months of pregnancy. My sister-in-law had her first baby just right after fetching and collect water. She went to hospital after collecting water and then deliver a girl. Even our mother grandmothers have been done like that. We cannot take rest. We will take rest only when it needed.

Q9. Don’t you think you are working harsh on your body?

Ans- we don’t know but, if we’re doing so, then we’re bound to do that. Out poverty makes us work like that.

Q10. Do you want the same thing for your children?

Ans- we still don’t know. But we’ll try to be different as we were. But if somehow our situation put us in front of the same faith as we were then we have to go for no option.

Q11. Do you want any alternate way if you can?

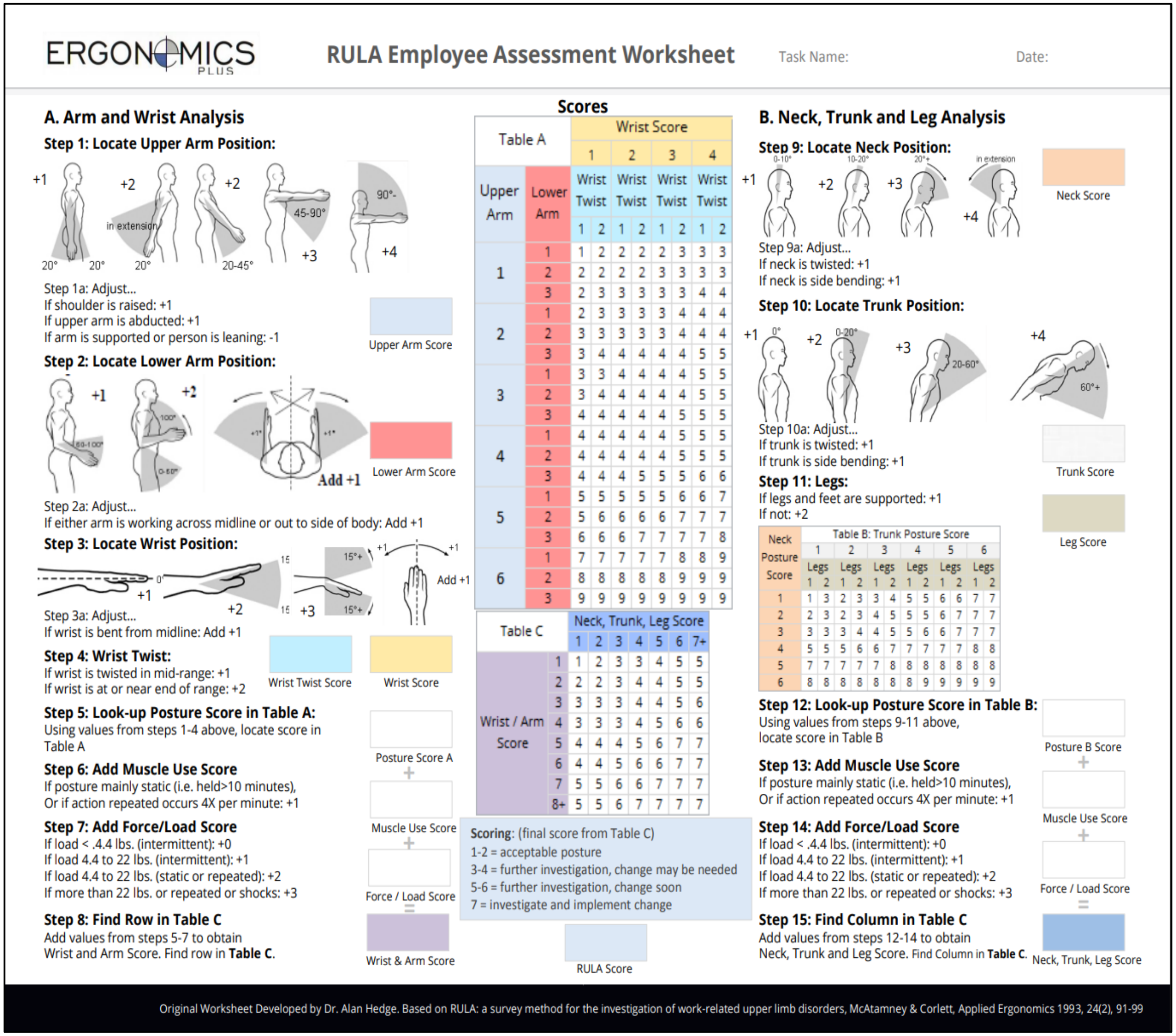
Ans- we don’t have that much amount of money, resource that we can use for alternated method such as tap, submersal, tube well. All we can depends upon the government of the state. Somehow, if they can help us, then we don’t have use rope, pulley, bucket for collection. Sometimes, wells are at such a distance that we have to walk at a distance to collect water. We don’t have to push our limit so far only in monsoon season. In monsoon season, because of the rain, the water level in the well becomes too high like we can extend our hands and collect the water. Maximum 5 ft. lower than the surface. But at the time of winter and summer, the water level went so low that it took too much time for one round of fetch. So, even if for sometimes, there’s no thought of alternation but time like summer and winter make us feel to have an alternate way. But our hands are tied.

Q12. What is your overall experience?

Ans- There is some good thoughts as well as sad thoughts. Good thoughts are their because, if we compare our water collection of villages with town, then you can say the that people from town are getting the hot water during summer and they are using fridge. But in village, the water comes from well is pretty much cold which can satisfy us while bath and drink. Same for winter, when, everyone needs warm water but got cold water from tank, meanwhile, when we fetch, we got warm water which is very much helpful in winter.But our opportunity & functions are limited. We live here with nature, nonpolluted area, getting cold water in summer and warm water in winter. But still the problem is on the body. We don’t fetch and have alternated because we like it just way it is but we don’t have other option.

APPENDIX III

RULA – RAPID UPPER LIMB ASSESSMENT



ERGONOMICS PLUS

RULA Employee Assessment Worksheet

Task Name:

Date:

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

+1 +2 +2 +3 +4

20° 20° in extension 20° 20-45° 45-90° 90°+

Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:

+1 +2 Add +1

60-100° 100°+ 0-60°

Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

+1 +2 +3 Add +1

0° 15° 15°+

Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Wrist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A
+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score
+

Step 7: Add Force/Load Score
If load < .4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score
=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in **Table C**.

Wrist & Arm Score

Scores

Table A		Wrist Score 1		Wrist Score 2		Wrist Score 3		Wrist Score 4	
Upper Arm	Lower Arm	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C	Neck, Trunk, Leg Score 1	2	3	4	5	6	7+
Wrist / Arm Score 1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

+1 +2 +3 +4

0-10° 10-20° 20°+ in extension

Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:

+1 +2 +3 +4

0° 0-20° 20-60° 60°+

Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Neck Posture Score	Table B: Trunk Posture Score 1		2		3		4		5		6	
	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture B Score
+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score
+

Step 14: Add Force/Load Score
If load < .4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score
=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in **Table C**.

Neck, Trunk, Leg Score

Original Worksheet Developed by Dr. Alan Hedge. Based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

APPENDIX IV

REBA – RAPID ENTIRE BODY ASSESSMENT

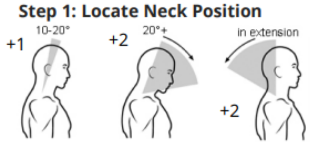
ERGONOMICS PLUS

REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

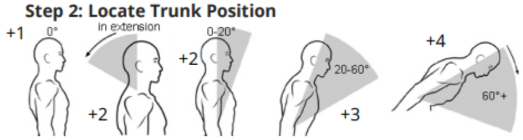
Step 1: Locate Neck Position



Neck Score

Step 1a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

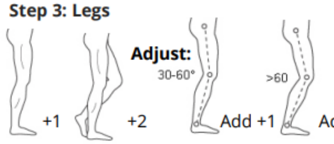
Step 2: Locate Trunk Position



Step 2a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 3: Legs



Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above,
Locate score in Table A

Posture Score A
+

Step 5: Add Force/Load Score
If load < 11 lbs. : +0
If load 11 to 22 lbs. : +1
If load > 22 lbs.: +2
Adjust: If shock or rapid build up of force: add +1

Force / Load Score
=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A.
Find Row in **Table C**.

Score A

Scoring
1 = Negligible Risk
2-3 = Low Risk. Change may be needed.
4-7 = Medium Risk. Further Investigate. Change Soon.
8-10 = High Risk. Investigate and Implement Change
11+ = Very High Risk. Implement Change

Scores

Table A	Neck	1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

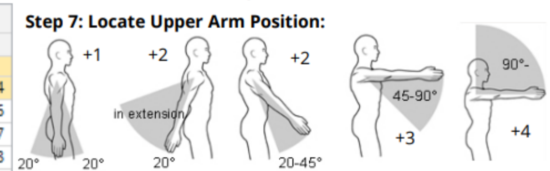
Table B	Lower Arm	1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C	Score B											
Score A	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score = REBA Score

B. Arm and Wrist Analysis

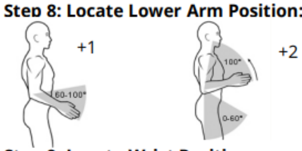
Step 7: Locate Upper Arm Position:



Step 7a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

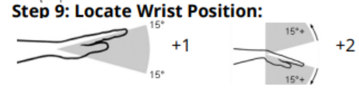
Upper Arm Score

Step 8: Locate Lower Arm Position:



Lower Arm Score

Step 9: Locate Wrist Position:



Wrist Score

Step 9a: Adjust…
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Posture Score B
+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, ***good: +0***
Acceptable but not ideal hand hold or coupling acceptable with another body part, ***fair: +1***
Hand hold not acceptable but possible, ***poor: +2***
No handles, awkward, unsafe with any body part, ***Unacceptable: +3***

Coupling Score
=

Step 12: Score B, Find Column in Table C
Add values from steps 10 &11 to obtain Score B. Find column in **Table C** and match with Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Original Worksheet Developed by Dr. Alan Hedge. Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

APPENDIX V

ART – (Assessment of Repetitive Task)

FREQUENCY AND REPETITION

A1 Arm movements

Observe the movement of the arm and select the category that is most appropriate. It is possible to select intermediate scores. Assess both the left (L) and right (R) arm.

		L	R
Arm movements are	Infrequent (eg some intermittent movement)	0	0
	Frequent (eg regular movement with some pauses)	3	3
	Very frequent (eg almost continuous movement)	6	6

A2 Repetition

This refers to movement of the arm and hand, but not the fingers. Observe the movement of the arm and hand and count the number of times the same or a similar pattern of motion is repeated over a set period of time (eg 1 minute). Assess both the left (L) and right (R) arm.

		L	R
Similar motion pattern of the arm and hand is repeated	10 times per minute or less	0	0
	11–20 times per minute	3	3
	More than 20 times per minute	6	6

FORCE

Use the grid to determine the level of force exerted with the hand and the amount of time that the force is exerted. It is possible to select intermediate scores on the grid if appropriate. If more than one type of force is exerted, select the highest score obtained with the grid.

There are two methods to determine the level of hand force:

~ Ask the person doing the work if there are any actions that require muscle effort of the arm, hand or fingers. If such actions are identified, ask the worker to describe the level of force involved in each action (eg light force, moderate force, strong force, or very strong force).

~ Otherwise, use the written descriptions below to determine the level of force exerted with the hand.

Light force	There is no indication of any particular effort
Moderate force	Force needs to be exerted. For example: ■ Pinching or gripping objects with some effort ■ Moving levers or pushing buttons with some effort ■ Manipulating lids or components with some effort ■ Pushing or forcing items together with some effort ■ Using tools with some effort
Strong force	Force is obviously high, strong or heavy
Very strong force	Force is near to the maximum level that the worker can apply

Worker's description of the level of force exerted with the hand

	Light	Moderate	Strong	Very strong
Infrequent	G0	A1	R6	Changes required*
Part of the time (15–30%)	G0	A2	R9	Changes required*
About half the time (40–60%)	G0	A4	R12	Changes required*
Almost all the time (80% or more)	G0	R8	Changes required*	Changes required*

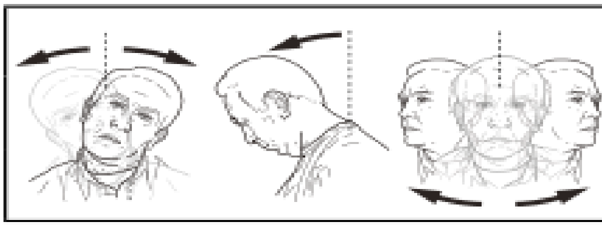
AWKWARD POSTURES

Determine the amount of time that the worker spends in the postures described below. This includes the time spent moving to a bent or twisted position repetitively and the time spent holding a bent or twisted position

C1 Head/neck posture

The neck is considered to be bent or twisted if an obvious angle between the neck and back can be observed as a result of performing the task.

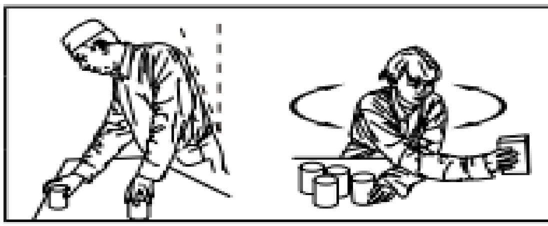
The head or neck is:

	In an almost neutral posture	0
	Bent or twisted part of the time (eg 15–30%)	1
	Bent or twisted more than half of the time (more than 50%)	2

C2 Back posture

The back posture is considered awkward if more than 20° of twisting or bending is observed.

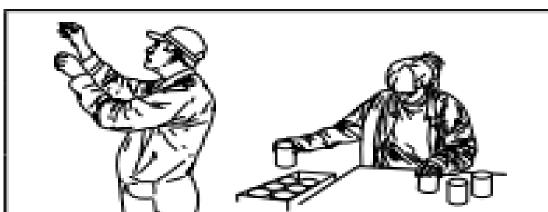
The back is:

	In an almost neutral posture	0
	Bent forward, sideways or twisted part of the time	1
	Bent forward, sideways or twisted for more than half of the time	2

C3 Arm posture

The arm is considered to adopt an awkward posture if the elbow is raised to around chest height and the arm is unsupported (eg not resting on a workbench).

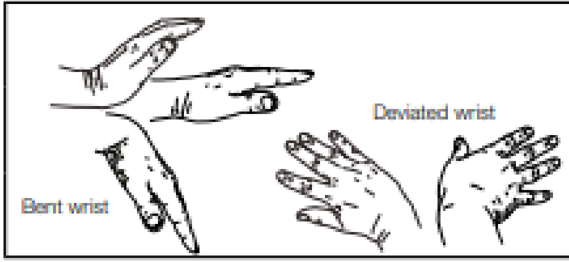
The elbow is:

		L	R
	Kept close to the body or supported	0	0
	Raised away from the body part of the time	2	2
	Raised away from the body more than half of the time	4	4

C4 Wrist posture

The wrist is considered to be bent or deviated if an obvious wrist angle can be observed.

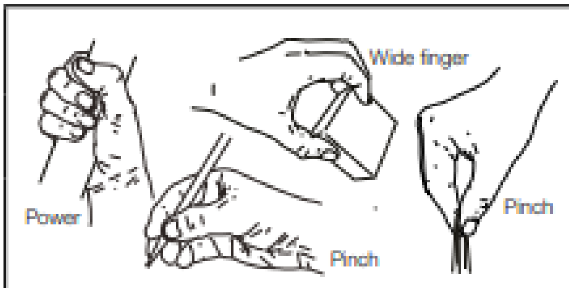
The wrist is:



	L	R
Almost straight/in a neutral position	0	0
Bent or deviated part of the time	1	1
Bent or deviated more than half of the time	2	2

C5 Hand/finger grip

The hands or fingers hold objects in a:



	L	R
Power grip or do not grip awkwardly	0	0
Pinch or wide finger grip for part of the time	1	1
Pinch or wide finger grip for more than half of the time	2	2

ADDITIONAL FACTORS

D1 Breaks

Determine the maximum amount of time that individuals perform the repetitive task without a break. Breaks are significant changes or pauses (eg of at least 5–10 minutes) in arm or hand activity. They include structured breaks such as meal breaks. They also include time spent performing other tasks that do not involve similar repetitive arm movements (eg a visual inspection task).

The worker performs the task continuously, without a break, for:

Less than one hour, or there are frequent short breaks (eg of at least 10 seconds) every few minutes over the whole work period	**0**
1 hour to less than 2 hours	**2**
2 hours to less than 3 hours	**4**
3 hours to less than 4 hours	**6**
4 hours or more	**8**

D2 Work pace

Speak to the workers about any difficulties they might have keeping up with the work. Select the most appropriate category. If the score is amber or red, ask for more information about this aspect of the work.

Not difficult to keep up with the work	**0**
Sometimes difficult to keep up with the work	**1**
Often difficult to keep up with the work	**2**

D3 Other factors

Identify any other factors that are present in the task. For example:

- glowes affect gripping and make the handling task more difficult;
- a tool (eg hammer, pick) is used to strike two or more times a minute;
- the hand is used as a tool (eg hammer) and struck ten or more times per hour;
- the tools, workpiece or workstation cause compression of the skin;
- the tools or workpiece cause discomfort or cramping of the hand or fingers;
- the hand/arm is exposed to vibration;
- the task requires fine precise movements of the hand or fingers;
- operators are exposed to cold or draughts or grip cold tools; and
- lighting levels are inadequate.

Select the most appropriate category. Assess both the left (L) and right (R) arm.

	L	R
No factors present	0	0
One factor is present	1	1
Two or more factors are present	2	2

D4 Duration

Determine the amount of time that a worker performs the repetitive task in a typical day or shift (excluding breaks). Select the most appropriate category.

Duration of task by a worker	Duration multiplier
Less than 2 hours	X 0.5
2 hours to less than 4 hours	X 0.75
4 hours to 8 hours	X 1
More than 8 hours	X 1.5

D5 Psychosocial factors

Psychosocial factors are not given a score. However, they should be considered, through discussion with workers, and, if present in the workplace, recorded on the score sheet. They include things such as:

- little control over how the work is done;
- incentives to skip breaks or finish early;
- monotonous work;
- high levels of attention and concentration;
- frequent tight deadlines;
- lack of support from supervisors or co-workers;
- excessive work demands; and
- insufficient training to do the job successfully.

Task description form

Assessor name:		Date:	
Company name:		Location:	
Name of task:			
Task description:			

What is the weight of any items handled?	

If items weigh more than 8 kg and the task involves manual handling consider using the MAC

Which side of the body is primarily involved?	Left		right		both	

What hand tools are used?	
Production rate (if available)	units per shift, hour or minute (circle as appropriate)
How often is the task repeated?	every seconds

Draw the breaks in the shift

First hour →

How long does a worker perform the task?	...without a break	hours
	...in a typical day or shift (excluding breaks)	hours
How often does an individual perform the task? (eg daily, weekly, etc)		
How often is the task carried out within the organisation? (eg daily, etc)		
Do workers rotate to other tasks? If so, what tasks?		

Score sheet

Enter the colour band and numerical score for each risk factor in the table below.
Follow the instructions on page 10 to determine the task score and exposure score.

Risk factors	**Left arm**		**Right arm**	
	Colour	Score	Colour	Score
A1 Arm movements				
A2 Repetition				
B Force				
C1 Head/neck posture				
C2 Back posture				
C3 Arm posture				
C4 Wrist posture				
C5 Hand/finger grip				
D1 Breaks				
D2 Work pace				
D3 Other factors				
Task score				
D4 Duration multiplier		**X**		**X**
Exposure score				
D5 Psychosocial factors				

Are there other indications that the task is high risk?

☐ The task or similar tasks have a history of ULDs (eg company accident book, RIDDOR reports, medically diagnosed cases of upper limb disorders).

☐ There are signs workers find the task difficult (eg wearing arm supports or bandages, reporting discomfort, aches or pains). Ask the workers if they have any of these symptoms.

☐ Other indications? If so, describe: