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Prediction Analysis of Human Motion Dynamics using Digital Human Modeling tool JACK

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Abstract

Background: Digital human modeling (DHM) offers human factors or ergonomics learner the promise of an efficient means to simulate a large variety of ergonomics issues early in the design of products and manufacturing workstations. Most of the products and manufacturing work settings are specified and designed by using sophisticated computer-aided design (CAD) systems. One can simulate issues regarding who can fit, reach, see, manipulate, and so on by integrating it.

Objectives: The objective of this study was to understand the behavior of different postures in constrained and awkward workplaces. Digital human modeling (DHM) software called JACK was used to obtain the posture data. It was compared with data collected through experimental studies in the laboratory. Observations were analized for the different activities like bend and arise, lifting, stooping, with and without load which majorly contributes for occupational hazard at workplace. The output generated used in positioning of machines and other equipment to optimize cycle time and avoid hazards. This case study was carried out on Press machine in bolt manufacturing process. Steel rod is used as raw material for making bolt. The workers were forced to perform task in awkward working position for lifting steel rod from its place in a very restricted position. Similar activities of different parts of the body occurred during the machine operation. It involves moving the material manually from using the left hand, holding and lifting from the ground, feeding it inside press machine using both the hands one by one in seventeen steps and Controlling the speed of the machine, collecting cut bolt parts after cutting it.

This paper focuses on the process of data acquisition which serves as an input for Force Solver, Lower Back Analysis. The data which is collected and identified as Non-Value adding activity was experimented in between time and Performance Level for the entire percentile ranging from 99, 95, 50, 5, and 1, using JACK Human Simulation tool.

Methods: Digital human modeling (DHM) JACK is process simulation software. It is considered for a digital representation of the human inserted into a simulation or virtual environment to facilitate prediction of safety and performance. DHM is intended to reduce or eliminate the need for

physical prototypes in new product and process design, and enables engineers of various disciplines to incorporate ergonomics science and human factors engineering principles in earlier phase in the design process. These methods can provide real cost savings alternative.

Conclusions: The critical evaluation and verification of the results are presented in the paper. The analysis of the different graph for the entire percentile manifested that most of the Joints are subjected to the incursion of high number of Forces during the verisimilitude time zone. It has been observed as the common activity of bend and arises in partial and full mode. Inference from the graphical representation is reflected and contributed in learning and prediction of the awkward postures. The outcome from the analysis will be helpful in future factoring the human element into manufacturing and the implementation of the proposed methods and technique. This result will add value in workstation design and safety for reducing occupational hazard and will bring competitive advantage.

Keywords: JACK, Modeling, Simulation, Force Solver, Percentile

1. Introduction:

The activities taken into consideration for study is from a bolt manufacturing firm in which an operator travel a distance to pick up the iron rod placed over ground and come back to the press machine for cutting operation. The steel rod was cut into seventeen number of cut parts for further process of manufacturing bolt. The occupational hazard due to bend and arise, turning lifting, stooping in partial and full mode. The observations were noted down in loaded and unloaded condition. These awkward positions were pointed out for the different motions of the operator handling the raw material steel rod from its place to the press machine and feeding it seventeen times in steps one by one for cutting. The data which was acquired for the different time spans for each of the activity is observed. Experimentation was conducted and interacted it with in a powerful graphical environment tool DHM. The system defaults dialog defines constraint solver parameters used by jack. Use caution when making changes to this dialog. These parameters affect the solution of user defined constraints and human behaviors and manipulations that make use of built-in constraints. Product and process designers in various engineering domains have experienced some limitations in predicting usability, safety, satisfaction, and human performance without a more substantial contribution from the practitioners with background and experience with the sciences of human factors and ergonomics. Practitioners in human factors and ergonomics have sometimes been limited in their contribution to team-based design efforts when their different languages have not always mapped well. Commercially available tools for computer-aided design incorporate some of the analysis tools specifically designed to support the physical aspects of an ergonomic analysis, The effective utilization of these tools is still primarily an engineering function and requires some depth of knowledge and perspective in human factors and ergonomics in order to know especially the capabilities, limitations, and best practices. JACK is a complete system for generating 3d environments or—virtual.

2. **Objectives:** Objective of using DHM (JACK) has been proved to be beneficial for considerable reduction of project timescale, design and manufacturing cost, occupational hazards, improvement of quality, productivity, and efficiency in diverse industrial sectors. It

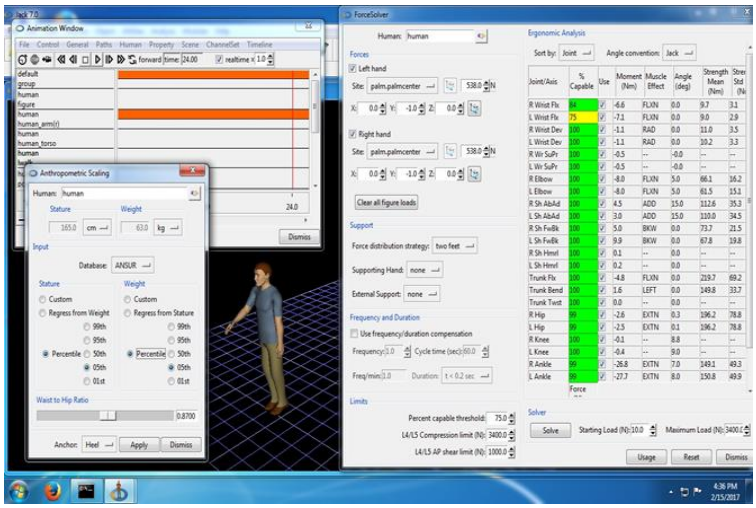
has expertise in deriving a relation between two parameters that is time and the force incurred on the different body joints in respect to the NIOSH standard. Modeling and Simulation (M&S) has gained significant foothold in all scientific disciplines. Modeling refers to representation of a system/model whereas simulation may refer to operation of model in a particular system of interest. Modeling and Simulation are performed in both real physical as well as in virtual environment (VE). VE is computer generated 3D graphics environment where various types of modeling and simulation activities can be performed. Foremost benefit of M&S in computer Graphics environment is the capability to perform detailed investigations without building physical prototype. While Modeling and Simulation plays a vital role in the Digital human modeling as an emerging area that bridges computer-aided engineering design, human factors engineering and applied ergonomics.

Table No. 01 - Time Zone activity wise

Activity	Time Span
Walking To	0-20
Arm Motion	20-25
Bend	25-35
Arise	35-45
Turn	45-55
Walking Fro	55-75

The human element is not being considered in ameliorating the productivity and in setting up appropriate facilities for the same. It was having a devastating impact on the total cycle time and was responsible for the occupational hazards to the concerned operators. It also evaluated thoroughly the manifestation of the identified activity and the scientific justification of the same is a problem which needs to be generalized.

3. Methods: Experimentation of Force Analysis with JACK:



Solver Parameters were used in the direction of the end effectors at fixed distance away. This process will cause the end effector to move more smoothly towards the real goal. These goals were far from the end effector; it is solved at intermediate step and was pointed more time to reach the goal due to the constraint. Constraint throttling parameter was used to control a solution whenever constraint cannot be found Active. Radio button had choice of on and off to disable or enable constraint throttling, but constraint throttling was on by default. Whether there is improvement or not but JACK even continues to solve the constraints, in all this process constraint throttling controls parameters every time. The constraint throttling was always kept on, in case there is no improvement greater than delta in the number of iterations specified for history size. The current solution is accepted and no further iterations are attempted until the goal moves.

History Size: The slider bar or edit field is Used to enter the number of Iterations. History Delta is used to edit the field to specify delta. Simulation Mode is used to indicate whether the solver should be active. Environment Update Optimization is used during active mode; this improves the performance of some manipulations and motions, and allows faster loading of large environment file group box to change how constraints are solved. Time Limit (ms) parameters were used in Jack for an iterative numerical procedure to evaluate the constraints. The amount of time the Jack required during one iteration before giving up and accepting a less than optimal solution could be calculated in solving this problem. This feature was controlled by the constraint time limit. Step Factor (m) was used to determine the motion by constraints which are likely to be smoother and less prone to being caught in local (not global) minima if the distance that the goal moved in one iteration was small. The constraint step factor provides a limit on the distance between the end effector and the goal. In place of actual goals, Jack uses intermediate goals placed in the direction of the end effectors at a fixed distance away mode.

In force analysis the activities has been simulated step by step in JACK. The different dynamics and motions have been drawn out for different percentile i.e., 99th, 95th, 50th, 5th & 1st set of population. The body part which is taken into consideration are 1-wrist (R), 2-wrist (L), 3-elbow (R), 4-elbow (L), 5- shoulder (R), 6-shoulder (L), 7-hip (R), 8-hip (L), 9-knee (R), 10-knee (L), 11-ankle (R), and 12-ankle (L) . All those joints were observed with and without load. The analysis of the forces which will fall over this body part were collected and inferences were presented with the help of graphical representation. Second wise force analysis of 95th percentile population for different body part in % (from 01 Sec to 75 Sec as per time span) is collected with the help of JACK and is mentioned in the Table no. 2 below.

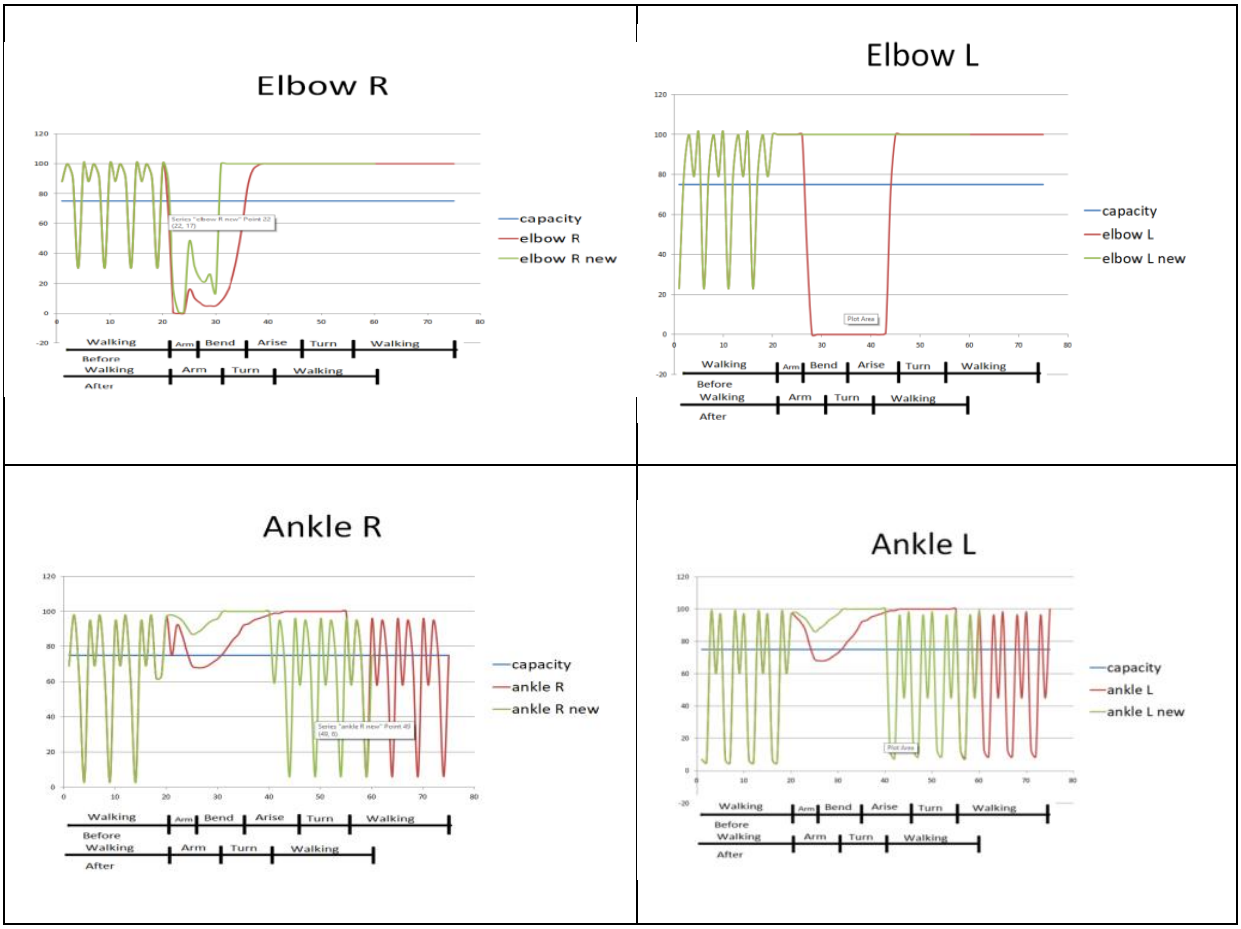
Table 2 – Second wise force analysis of 95th percentile population for different body part in % (from 01 Sec to 75 Sec as per time span)

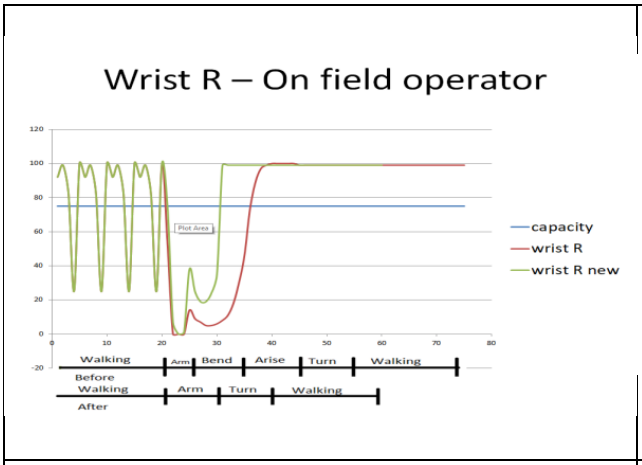
1	2	3	4	5	6	7	8	9	10	11	12
82	80	100	93	100	100	99	99	84	86	73	7
84	76	100	99	100	100	99	99	91	100	99	4
85	75	99	100	100	100	99	99	99	93	63	98
83	78	94	100	100	100	99	99	97	73	2	66

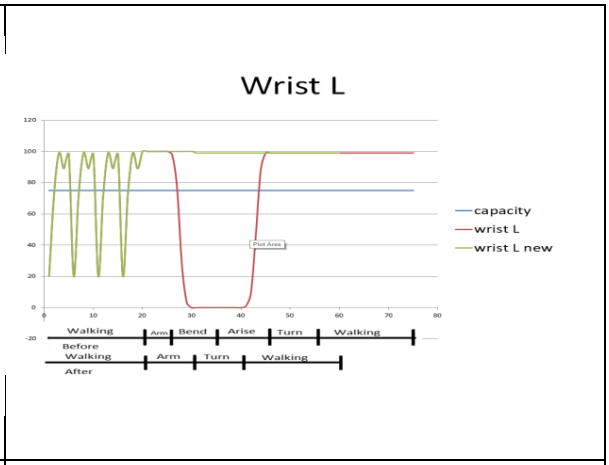
80	81	100	100	100	99	99	99	98	99	88	93
82	80	100	93	100	100	99	99	83	87	72	7
84	76	100	99	100	100	99	99	91	100	99	4
85	75	99	100	100	100	99	99	99	93	63	98
83	78	94	100	100	100	99	99	97	73	2	66
80	81	100	99	100	100	99	99	98	99	88	93
82	80	100	93	100	100	99	99	83	87	72	7
84	76	100	99	100	100	99	99	91	100	99	4
85	75	99	100	100	100	99	99	99	93	63	98
83	78	94	100	100	100	99	99	97	73	2	66
80	81	100	100	100	100	99	99	98	99	88	93
82	80	100	93	100	100	99	99	83	87	72	7
84	77	100	99	100	100	99	99	91	100	99	4
85	75	99	100	100	100	99	99	99	93	63	98
83	78	94	100	100	100	99	99	97	73	2	66
83	77	100	100	100	100	100	100	100	100	97	96
86	77	64	100	100	100	99	99	100	100	99	99
94	77	1	100	97	100	99	98	100	100	90	90
99	77	0	100	9	100	98	98	99	99	84	83
2	77	0	100	30	100	96	96	97	97	70	72
0	77	40	100	78	100	94	93	93	93	58	60
0	77	9	100	76	100	93	93	93	92	58	58
0	79	6	45	75	100	93	93	93	92	58	58
0	81	4	0	77	100	94	93	93	93	59	59
1	84	4	0	79	100	94	94	94	94	61	61
20	87	5	0	84	100	95	94	95	95	64	64
71	91	7	0	89	100	95	95	96	96	68	68
98	94	11	0	93	99	96	96	97	97	73	73
100	96	19	0	97	99	97	97	98	98	78	78
94	98	33	0	99	98	98	98	99	99	83	83
65	99	54	0	100	98	98	98	100	100	89	89
94	98	56	0	100	98	98	98	99	99	88	88
100	97	61	0	99	99	98	98	99	99	88	88
99	94	60	0	99	99	97	97	99	99	87	88
81	92	72	0	99	99	96	97	98	98	87	87
85	89	0	0	100	100	100	100	98	98	100	100
84	86	4	0	100	100	100	100	99	99	100	100
84	82	36	0	100	100	100	100	99	99	100	100
83	80	86	1	100	100	100	100	99	99	100	100
82	78	99	79	100	100	100	100	100	100	100	100
82	78	100	100	100	100	100	100	100	100	100	100
84	86	4	0	100	100	100	100	99	99	100	100
84	82	36	0	100	100	100	100	99	99	100	100

83	80	86	1	100	100	100	100	99	99	100	100
82	78	99	79	100	100	100	100	100	100	100	100
82	78	100	100	100	100	100	100	100	100	100	100
81	79	100	100	100	100	100	100	73	93	63	13
84	75	100	100	100	100	100	100	83	100	97	5
84	75	100	100	100	100	100	100	100	89	71	97
82	78	100	100	100	100	100	100	99	60	5	52
80	81	100	100	100	100	100	100	98	98	90	96
81	79	100	100	100	100	100	100	73	93	63	13
84	75	100	100	100	100	100	100	83	100	97	5
84	75	100	100	100	100	100	100	100	89	71	97
84	75	100	100	100	100	100	100	100	89	72	97
82	78	100	100	100	100	100	100	99	60	5	52
83	77	100	100	100	100	100	100	100	100	98	98

Fig. 01 Showing Analysis of forces on the different Joints of the complete body:




Wrist R – On field operator
capacity
wrist R
wrist R new
Walking
Arm
Bend
Arise
Turn
Walking
Before
Walking
Arm
Turn
Walking
After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Before
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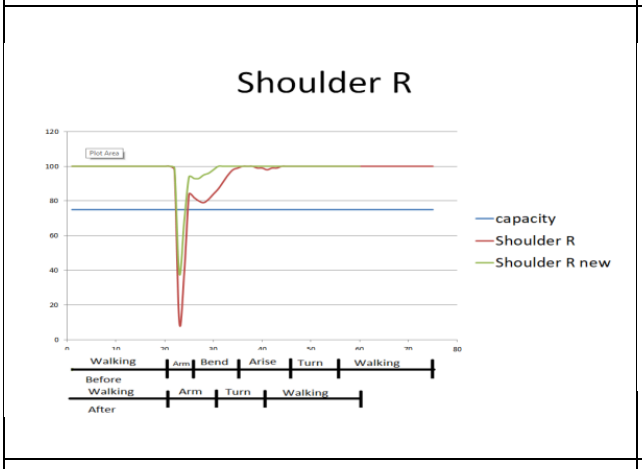
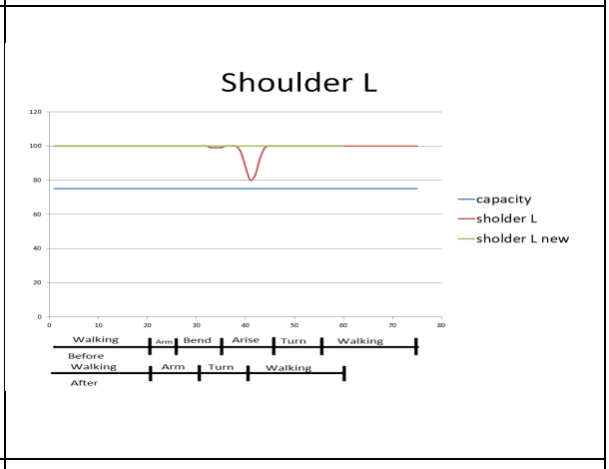
Arm
Turn
Walking
After


Shoulder R
capacity
Shoulder R
Shoulder R new
Walking
Arm
Bend
Arise
Turn
Walking
Before
Walking
Arm
Turn
Walking
After


Shoulder L
capacity
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sholder L new
Walking
Arm
Bend
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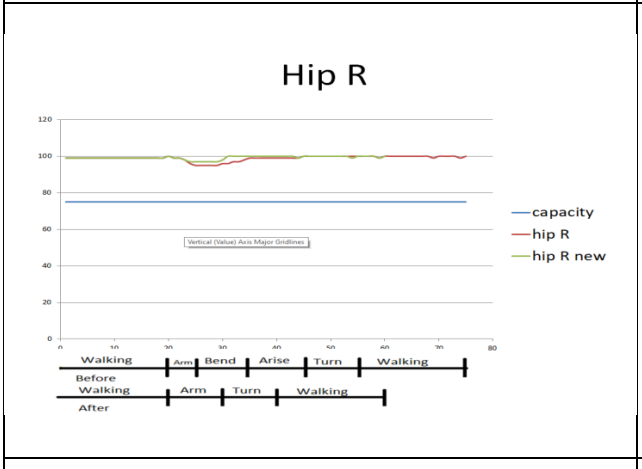
Walking
Before
Walking
Arm
Turn
Walking
After


Hip R
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hip R
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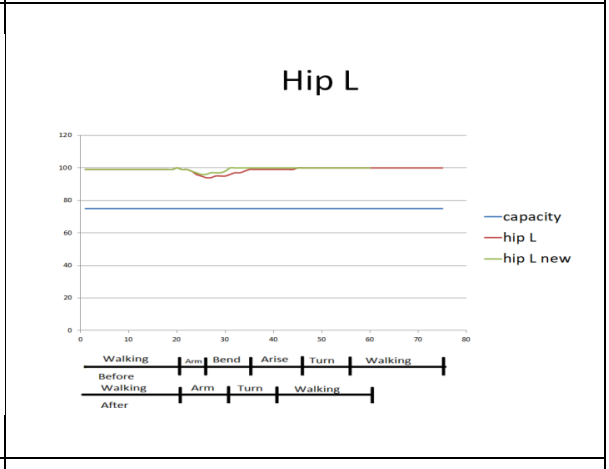
Walking
Arm
Bend
Arise
Turn
Walking
Before
Walking
Arm
Turn
Walking
After


Hip L
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hip L
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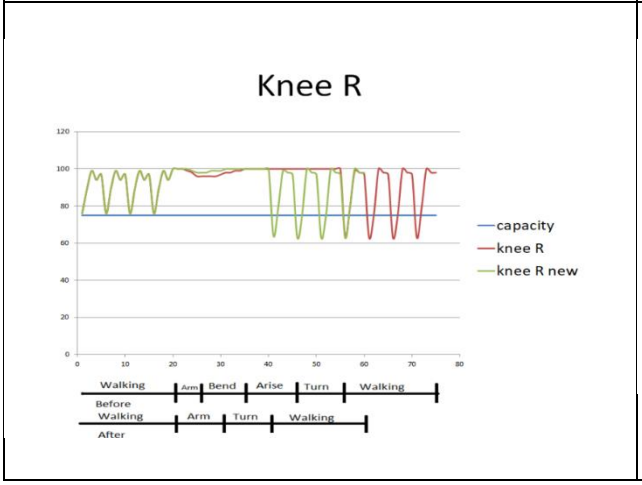
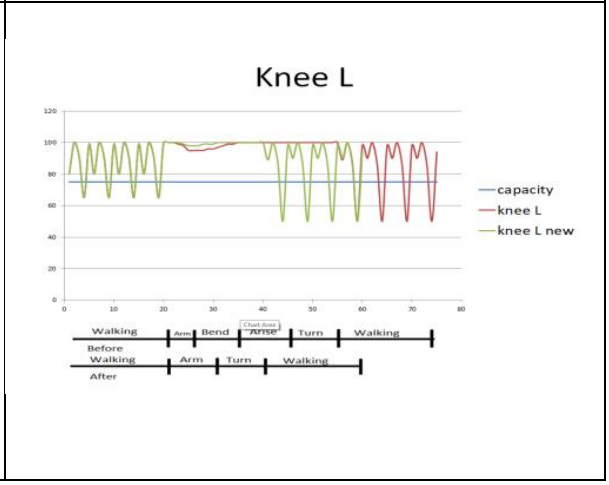
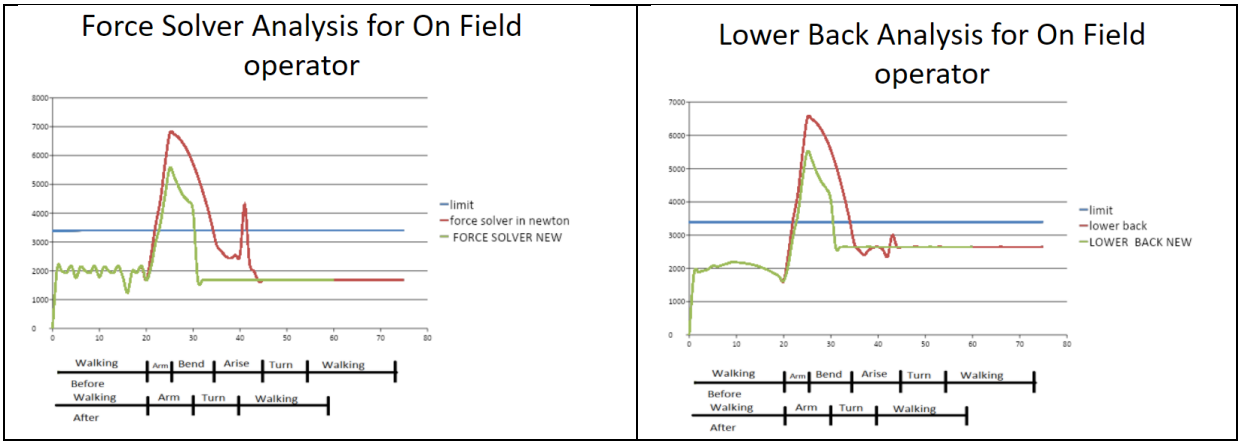
Walking
Arm
Bend
Arise
Turn
Walking
Before
Walking
Arm
Turn
Walking
After


Knee R
capacity
knee R
knee R new
Walking
Arm
Bend
Arise
Turn
Walking
Before
Walking
Arm
Turn
Walking
After

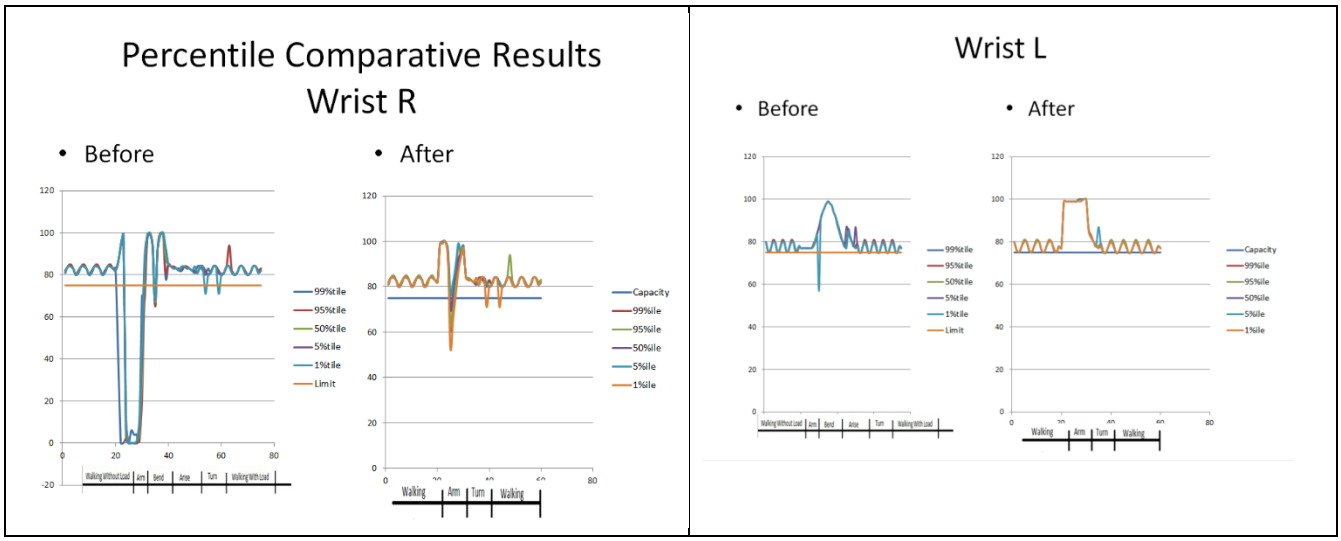

Knee L
capacity
knee L
knee L new
Walking
Arm
Bend
Arise
Turn
Walking
Before
Walking
Arm
Turn
Walking
After



4. Result: Analysis of forces on the different Joints is compared for the different time zone and activities. It is mentioned in the table as below. The results obtained were calculated and the analysis is made on the basis of before and after bend and arises. Those analysis are shown in the Fig.02 below. It is observed that most of the Joints are subjected to the incursion of high number of Forces during the study time zone.

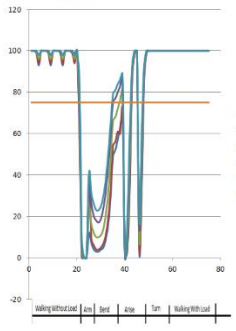
Time Zone			
Before		**After**	
Activity	Time Span	Activity	Time Span
Walking	0-20	Walking	0-20
Arm motion	20-25	Arm motion	20-30
Bend	25-35	Turn	30-40
Arise	35-45	Walking	40-60
Turn	45-55		
Walking	55-75		

Fig.02 Activities and Analysis before and after :

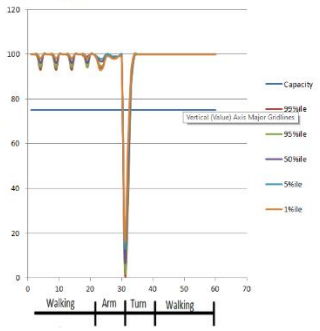


Elbow R

Before

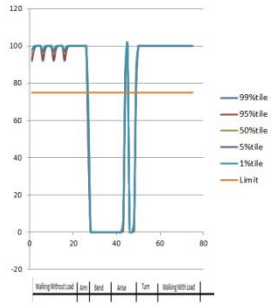


After

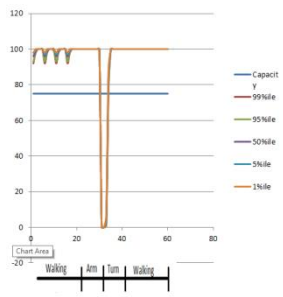


Elbow L

- Before

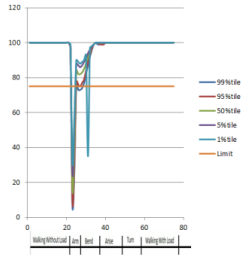


- After

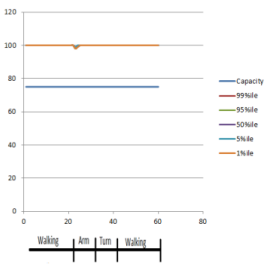


Shoulder R

- Before

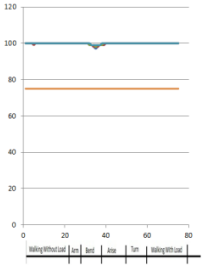


- After

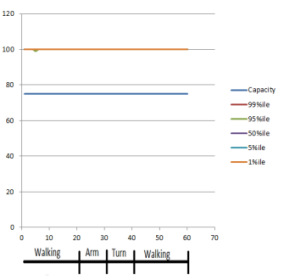


Shoulder L

- Before

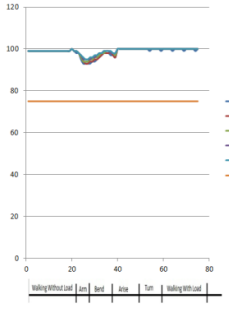


- After

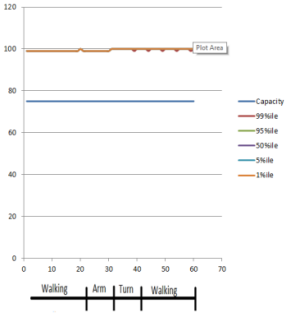


Hip R

- Before

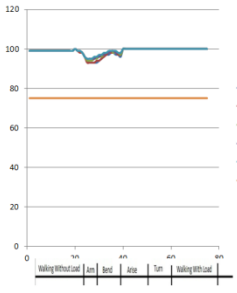


- After



Hip L

- Before



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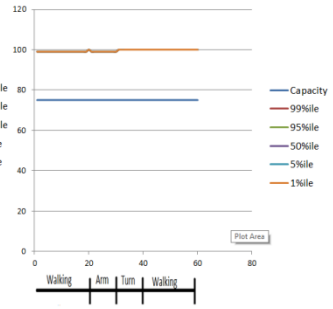
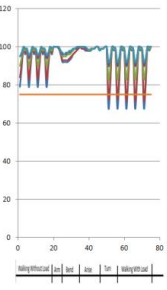
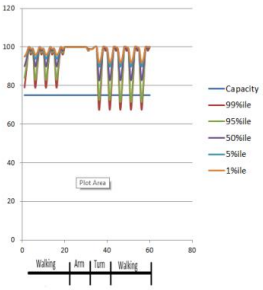


knee R

- Before

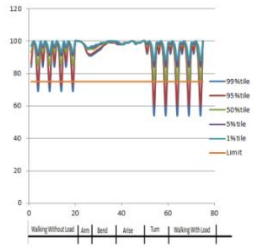


- After

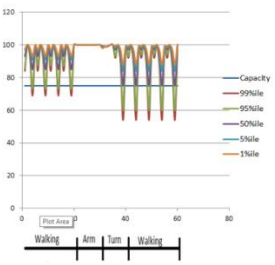


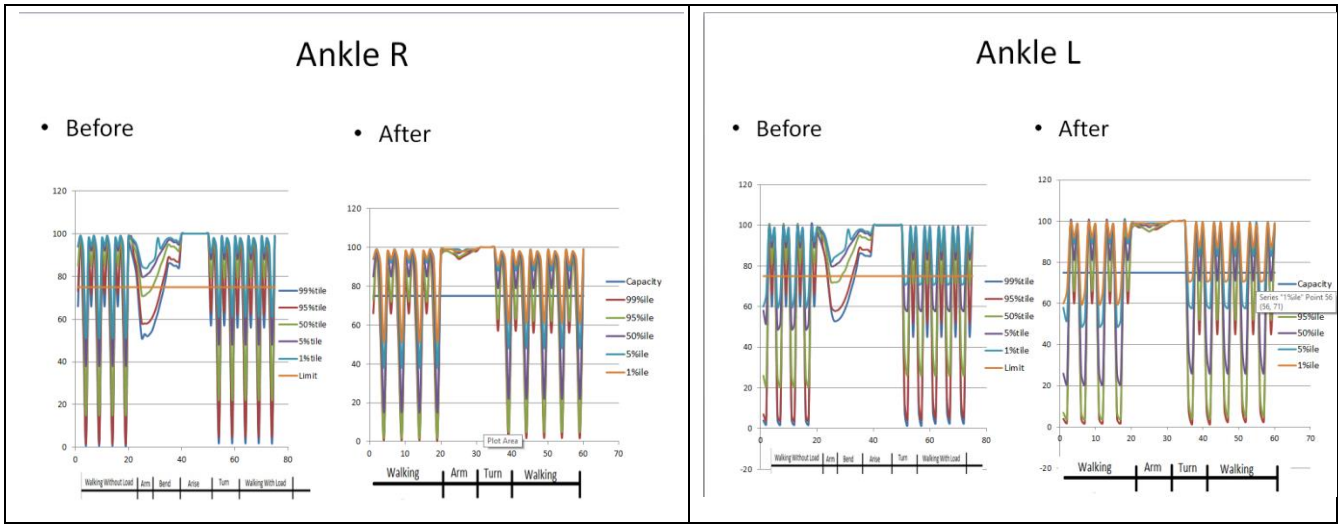
knee L

- Before



- After





5. fDiscussion: Digital Human Modeling tools simulate a task performed by a human in a virtual environment and provide useful indicators for ergonomic, universal design and representation of product in situation. The latest developments in this field are in terms of appearance, behavior and movement. With the considerable increase of power computers, some of these programs incorporate a number of key details that make the result closer and closer to a real situation. With the differences in terms of performance, qualities, limitations, the choice of the tool becomes complicated in this wide range of possibilities. In this context, can study and compare the most of human modeling software available for testing and enhancing reliability of the result to help the designer to get the most adaptable tool.

6. Conclusion: The current study is focused on to validate whether the data collected in the laboratory for the different awkward posture at the workplace for different anthropometric percentile values meets the ergonomic requirement. Here different percentile occupant models of male and female are built by JACK software, and the basic postures and typical activities are decomposed in detail. The corresponding simulation analysis modules of JACK are chosen for evaluating different postures, and the final results shows that the most of the Joints are subjected to the incursion of high number of Forces during the study time zone. The data collected and analyzed in the lab were validated the result using JACK. The different awkward postures were finally optimized, which will be useful to achieve the desired effect of economy, safety and comfort.

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