Digital Human Modeling and Simulation for Virtual Ergonomics Evaluation
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Lecture – 16
Techniques/Process of Virtual ergonomics evaluation using DHMs Part B (Part III)

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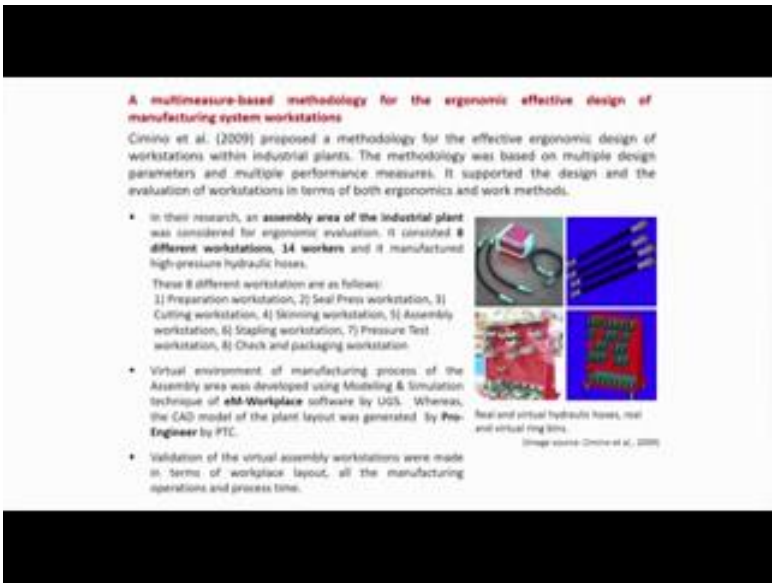

Cimino et al 2009 in the research paper multi measure based methodology for the ergonomic effective design of the manufacturing system workstation. They proposed in this research paper a methodology for the effective ergonomic design of workstation within industrial plants. The methodology was based on multi design parameters and multiple performance measures. It supported the design and evaluation of workstations in terms of both ergonomics and work methods.

In their research an assembly area of industrial plant was considered for ergonomic evaluation. It consisted of 8 different workstations, 14 workers and it manufactured; this particular workstation was involved in the manufacturing of hydraulic hoses. This 8 different workstation are as follows; first one is the preparation workstation, second one seal press workstation, third cutting workstation, fourth skinning workstation, fifth assembly workstation, then sixth stapling workstation, seventh pressure test workstation, and eighth the check and packaging workstation.

So, in this particular assembly area, where these 8 workstations are there they evaluated. Virtual environment of manufacturing process of the assembly area was developed using modeling and simulation techniques of eM work place software by UGS. Whereas, the CAD model of the plant layout was generated by pro engineer's software. So, mainly for

this particular research they use 2 softwares; one is eM work place and another is Pro e. With this eM work place mainly they used for virtual manufacturing process assembly and assembly mean how those work are being carried out. On the other hand this Pro e software, they used for modeling various components in that workstation.

Validations of the virtual assembly workstation were made in terms of work place layout, all the manufacturing operations and process time. So, these three areas they mainly concentrated; one is the overall layout another is the manufacturing operation and process time. So, here is the image; from this image the left side is the real hydraulic hoses and the right side are the virtual one. This is hydraulic hoses and this is the real and virtual rings bins, where the rings are kept. So, this left side is real scenario and the same thing while it is developed in the CAD, these are the CAD model.

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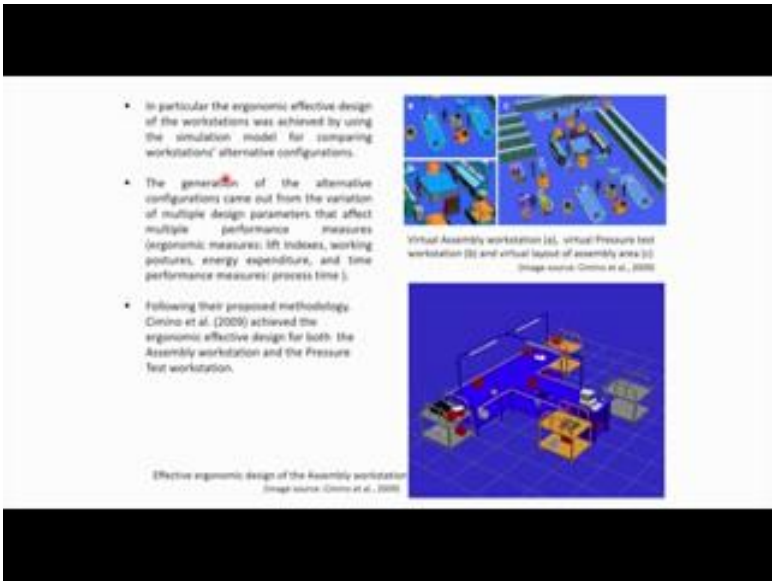

Now, in particular the ergonomic effective design of the workstation was achieved, but using the simulation model for comparing workstation alternative configuration. So, for effective ergonomic design purposes what researchers did, they went for various types of alternation. So, out of this alternates they positioned the various components in different layout condition and studied which is more effective for manufacturing system and so that the workers can work comfortably and the overall productivity of that manufacturing unit or that assembly area can be enhanced.

So, there are the virtual assembly workstation; a, is the virtual pressure test workstation and b is the virtual layout assembly area and so virtual assembly a. Here, a, b and c this three images and the caption of the three images are provided. So, first one is the virtual assembly workstation. So, this is that a virtual assembly workstation then b is the virtual pressure test workstation and c is the virtual layout of the assembly area. So, for all this

three workstation they developed the CAD model then populated with the digital human model and then evaluated.

The generation of the alternate configuration came out from the variation of multiple design parameters that affect multiple performance measures. Those ergonomic measures which are followed in this particular research, those are lift indexes working postures energy expenditure and time performance measure and process time. So, based on this various ergonomic measures, they ultimately analyzed various alternatives that which alternative is the best for their internet purpose following their proposed methodology.

Cimino et al. 2009 achieved the ergonomic effective design for both, the assembly workstation and the pressure test workstation. So, here this is the image of effective ergonomic design of the assembly workstation. So, this is the situation in the existing workstation, but after ergonomic evaluation with measuring all this performance measures then finally, they proposed for the assembly workstation this will be the plant layout or the area layout.

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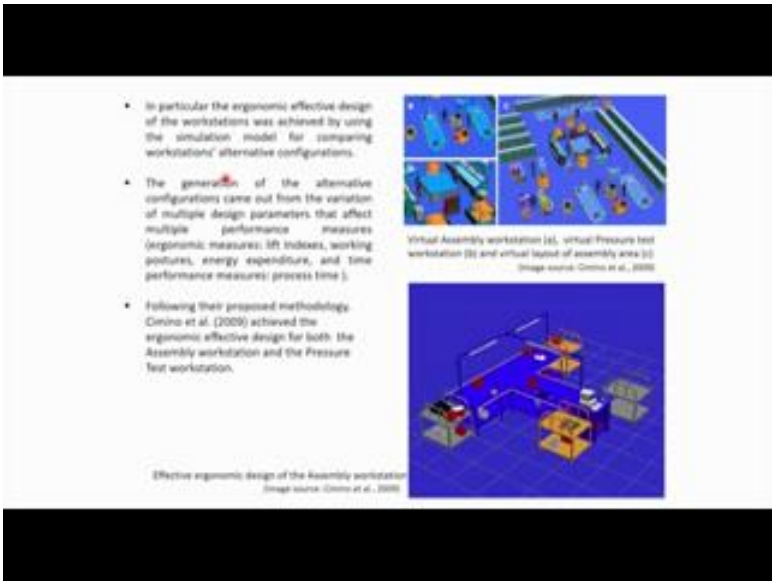

In another research paper by Santos et al. 2007 in that their title of the research paper is using ergonomic software in non-repetitive manufacturing process because many other research paper, they mainly concentrated repeated type of task and in this manufacturing work places are people are undergoing various types of repetitive task and how they are being affected due to that type of task have been analyzed, but in this particular research papers, Santos et al. mainly concentrated on non-repetitive manufacturing process.

So, they used digital human model based studies of small medium enterprises and case study was carried out on non-repetitive manufacturing process. As I mentioned earlier in the research, a furniture manufacturing workstation involved in production of small lots with a large variety of parts types and size. So, that workstation which they identified for their study that was actually involved for production of small various types; small equipment parts of varying size and dimension and types the work place included a machine that is a milling machine that was continuously being operated by a worker. So, this is the virtual layout of that work place virtual environment of the workstation was developed using the cad model of eM work place software.

Reported study allowed the analysis of ergonomic conditions of the work place and reduction of idle time various steps followed in the ergonomic design of the work place and method time study are as follows. So, in the research they followed various ergonomic designs of the work place and method time study. So, for this purpose they followed these steps.

So, first step that is the description of the task in that description they have defined various task, which are been performed in that work place, various task included in the work cycle are; first one is bringing the board closer, second measure the piece, register the board, fourth is change the NC part program then fifth adjust the board, sixth is the milling process, seventh check and clean the board and tool change for all this eight task from all this task how is the posture of the people that was studied, and accordingly that was simulated in the virtual environment of the eM work place software.

So, these are the few images are various activities as we mention various task are there. So, various tasks are being performed by the virtual human model or the digital human model the following the task definition next step is the conducting experiments.

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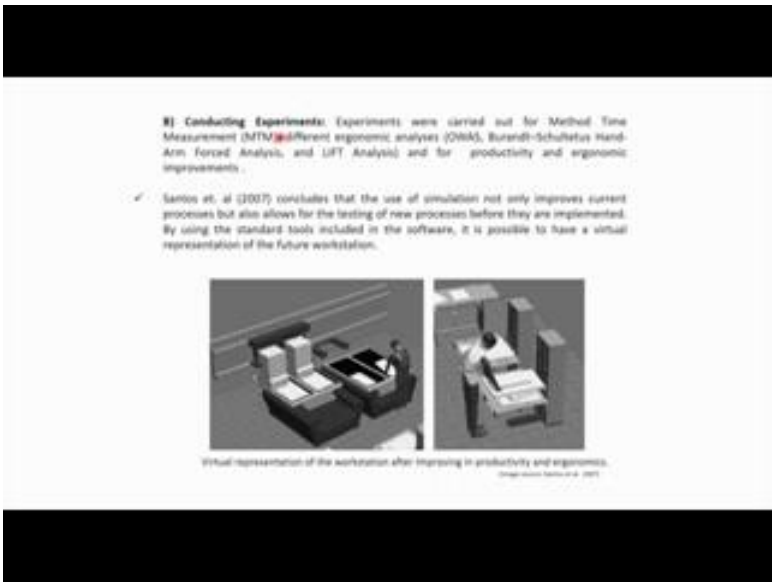

Various experiments are carried out for method time measurement different ergonomic analysis. So, whichever ergonomic analysis are carried out in this particular research it was OWAS work working posture analysis system then Burandt Schultetus hand arm force analysis, lift analysis and for productivity and ergonomic. So, these tests are ultimately conducted for productivity and ergonomic improvements of that work place.

Santos et al. 2007 concluded following their research that the use of simulation not only improves the current process, but also allows the testing of new processes before they are being implemented by using standard tools included in the software. It is possible to have virtual representation of the future workstation. So, this image is virtual representation of the workstation after improving the productivity and ergonomics.

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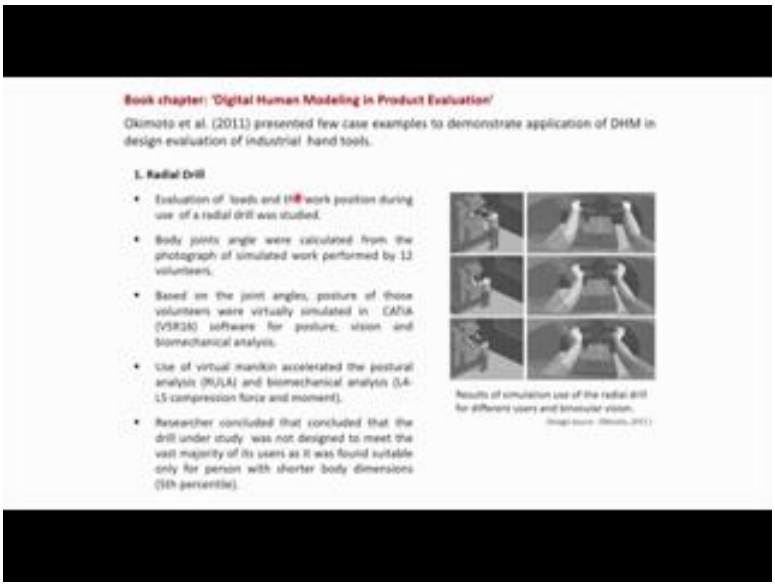

Now, we are going to discuss one book chapter. In this book chapter; title of the book chapter is 'Digital Human Modeling in Product Evaluation'. So, in that particular chapter Okimoto et al. 2011 presented few case examples to demonstrate the application of digital human model in designing various industrial hand tools or industrial machines. So, first one is the radial drill.

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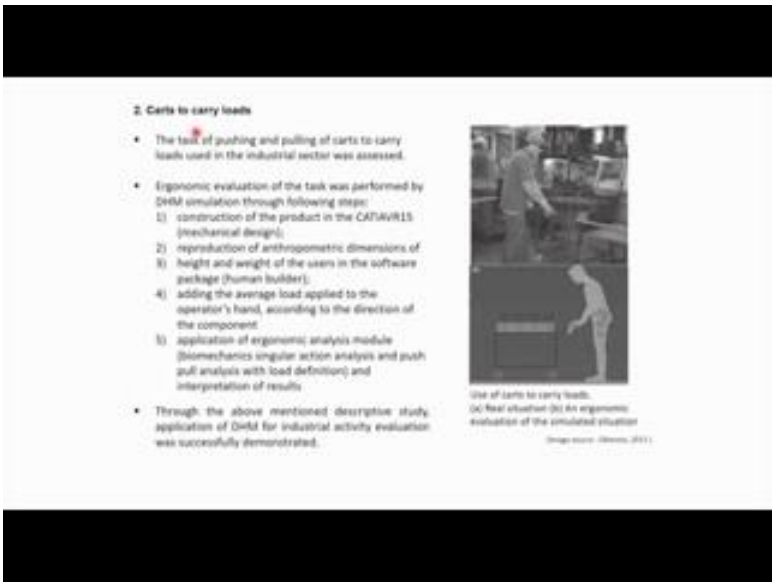

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Second carts to carry loads and third one are the accessibility in wheelchair. So, these three aspects they studied in this paper. So, first one is the radial drill evaluation of loads and the work position during use of radial drill was studied and it was reported in this particular book chapter body joints angle are calculated from the photograph of simulated work performed by 12 volunteers. So, while that 12 volunteers were performing that activity that was photograph and based on the marker placed on their

body joints body joints angles are calculated and based on that calculation it was possible to simulate the same body posture. In the digital human modeling software and digital human model was given appropriate working posture.

So, based on the joint angles as I mentioned posture of those volunteers are virtually simulated in CATIA v5 software and analysis was done for posture vision and other biomechanical analysis use of virtual manikin accelerated the postural analysis that is rule here and biomechanical analysis that is L4 L5 inter vertebral decompression then different types of moment. So, that was studied and it was found that digital human modeling software is very much helpful and it helps to evaluate this posture and biomechanical aspects.

Researcher concluded that the a drill under study was not designed to meet the majority of the user because the following this analysis, they found the dimension of the drill is suitable only for the lower percentile operator means people with shorter body dimension, for example, fifth percentile body dimension they can operate the drill machine easily, but it is not suitable for higher percentile digital human model because to use that; one they adopt bend posture or awkward working posture, second the product they evaluated that is the carts to carry loads.

So, here is that image, in that industrial work place workers are using this type of cart for carrying various types of load from one place to another the task of pushing and pulling of carts to carry loads used in the industrial sector was assessed in this particular book chapter and it was reported here. So, ergonomic evaluation of the task was performed by digital human modeling and simulation through the following steps. So, these steps are first one construction of the product in CATIA v5 software that is the mechanical design aspect of that software, then production of anthropometric dimension reproduction mean they measure the body dimension of the worker and the same body dimension has been put in digital human modeling software to develop the digital human models height and weight of the users in the software package using human builder tool.

Next step is the adding the average load applied to the operators hand according to the direction and the direction of the component. So, then they defined the load which is being handled by the operator. So, first they develop the cart model with that cart model then they develop the digital human model based on the anthropometric data and also defined the load that how much load that person is been handled that was also defined for low load analysis; load handling analysis by the digital human model then application of ergonomic analysis module that is biomechanical single action analysis and push pull analysis.

These tools are available in this CATIA software. With those tools they evaluated and interpreted the result through the above mentioned descriptive study application of DHM for industry activity evaluation was successfully demonstrated. So, from this case study they clearly demonstrated that digital human modeling software is very much effective very much beneficial for evaluating this type of pulling push pull or load carry task based on that analysis. They can modify the cart for carrying loads then accessibility of wheelchair this was also reported in that particular book chapter.

So, for this wheelchair evaluation, actually this part, this evaluation was done for a society social housing complex. So, the study was performed to evaluate the accessibility of social housing for low income family in the Sambaqui village in Brazil. So, for that particular village while they people are developing that social housing of low cost for the low cost family then before developing the actual room environment. They made it in CAD software and evaluated and tried to find out what types of problems may appear while those houses are being used by disabled people particularly wheelchair.

Following physical observation and dimensional data collection environment of the houses are simulated using CATIA v5 that is version 16 with that software they developed the environment of that room condition that is the environment layout of that room with popularity different types of furniture as it is mentioned in the next paragraph. So, furniture wheelchair and equipment present in those houses including window frames, doors, dishes and household objects are modeled and populated with digital human virtual human models. So, various furniture's and various objects inside that house are simulated in CAD software and digital human model was also positioned to analyze whether that housing complex is usable for this human and their main target.

As I mentioned, the main target was for disabled and wheelchair user the CAD model of the housing layout with furniture facilities access to locks use of bathrooms and opening the door and drawers in existing furniture are evaluated for accessibility by disabled people specifically, wheelchair users. Following the study it was concluded that the use of digital human model software facilitated more detailed ergonomic assessment than which is possible through direct observation or various types of indirect method.

So, without developing or without making the actual arrangement in physical prototype, it was possible to understand that what problem this wheelchair user or disabled people can face that can be evaluated in virtual environment of digital human modeling software.

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Now, we are going to discuss one more paper where digital human modeling software is used for industrial work place evaluation and their soliciting modification for that workstation. So, title of this paper is redesign of work accessories towards minimizing awkward posture and reduction of work elements of a work cycle in shop floor workstation. So, shop floor workstation activities in small and medium scale injection molded plastic furniture manufacturing industry.

So, how is the shop floor? So, this is the overall view of that research paper, what this research paper is dealing with. So, existing risk factors awkward working posture improper design of the work place and accessories manual material or load handling, these are the existing risk factor in that workstation. So, in this particular research paper the intended workstation is the shop floor workstation in granulator workstation of plastic furniture manufacturing sector.

So, data are collected through questionnaire body part discomfort may be noted. Questionnaire was used direct observation and photography was done then posture was evaluated with OWAS and REBA technique and work study was performed by operation chart. So, this is the existing condition in that workstation how operators in those workstations are working and the same thing has been simulated in CAD environment evaluation and validation of the design proposals using CAD and digital human modeling software was also performed. So, main aim of that research was to for the mitigation of risk factors through design intervention.

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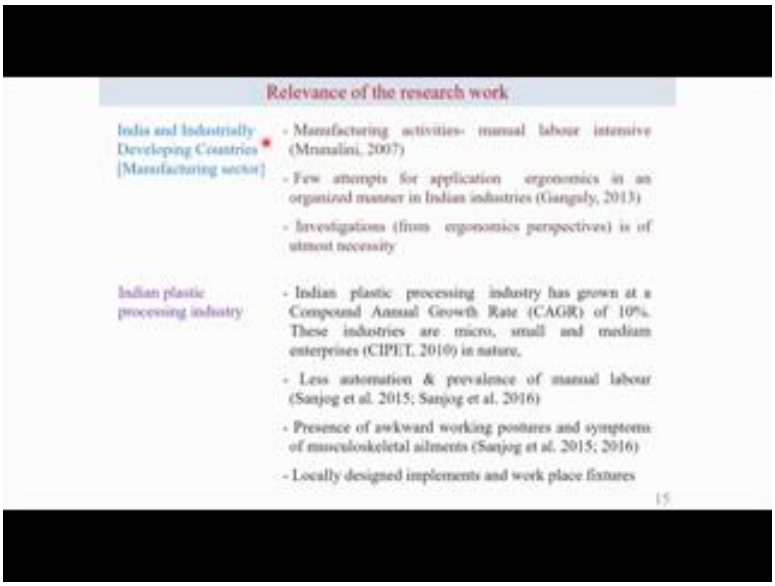

Now, relevance of the research work, this is actually reported from India. So, in the India and industrially developing countries this is very relevant for this particular research because manufacturing activities manual is labor intensive as reported by Mrunalini 2007. So, in India and industrially developing countries these manufacturing sectors are labor intensive, only very few attempts has been done, has been taken for applying ergonomics in organized manner in Indian industries as reported by Ganguly 2013.

Investigations from ergonomics perspectives is of utmost necessary for this purpose because in industrially developing countries like India, there is very less application of ergonomic study or ergonomic principle in those work spaces and there after design modification or redesign of the work place that is very less reported. So, there is requirement of investigation from ergonomics perspective.

Now, if we discuss about industrial plastic, Indian plastic processing industry then we will find in Indian scenario, the Indian plastic processing industry has grown at compound annual growth rate of 10 percent. These industries are micro small and medium enterprises. So, this research was carried out because this is very emerging field in India and this industry is growing at a faster rate as it is mentioned here, and less automation and prevalence of manual labor is also reported by other by the same researcher Sanjog et al. 2015 as well as 2016.

Presence of awkward working posture and symptom of musculoskeletal ailments are also present there and locally designed implements and work place fixtures are visible there. So, if you look at the India's Indian plastic furniture manufacturing sectors, there are the tools and equipment's which are being used. Many of those tools and equipment's or

work accessories are actually designed by the local artisans or that is designed implements and work fixtures are designed by the factory workers themselves.

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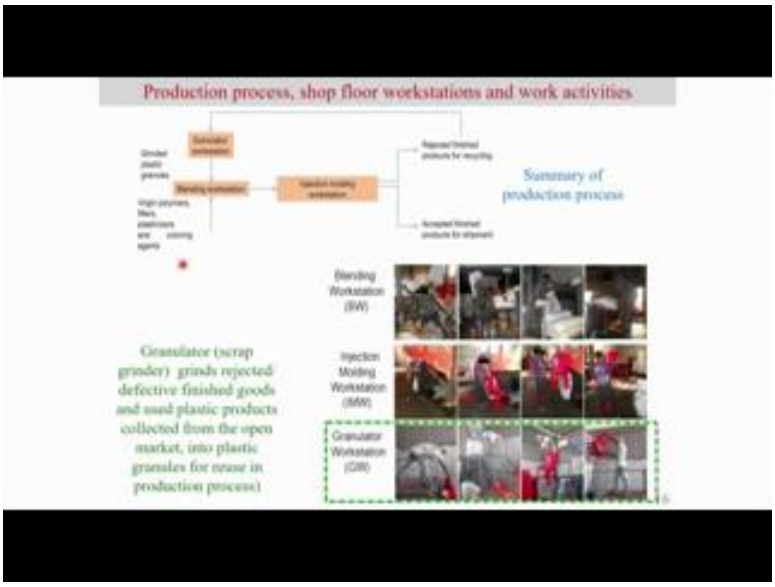

So, although, this research paper actually reported on granulated workstation, in plastic furniture factory there are three types of workstation; one is blending workstation, one is granulated workstation and one is the injection molding workstation. So, different workstations have different roles. So, injection molding workstations is a main workstation where the actual plastic furniture is been produced. If that final product is acceptable then it goes for shipment and if we find the product is rejected or there is some defect then again it goes to granulator workstation.

So, role of the granulator workstation is to grind that defective plastic furniture or otherwise other plastic furniture's or plastic materials collected from the open market that is also grinded and that granules are then transferred to blending workstation the role of blending workstation, what it is actually involved for that it mixes the virgin polymers fillers plasticizers and coloring agent and when that the materials is ready then that material is shifted to injection molding workstation or making those plastic furniture's. So, as I mentioned main role of the granulator workstation is actually granulator or scrap grinder grinds reject or defective finished goods and used plastic products collected from the open market into plastic granules for reuse in the production process.

Although three types of workstations are involved and their activities are also different as depicted from this images. So, this is the image from blending workstation these are the images from injection molding workstation and this are the images from granulator workstation. In this particular research paper reported research is concerning with granulator workstation where the activities are like this that workers has to lift that chair

or they have to lift it that chair from the stack, then they have to put it in the granulator machine.

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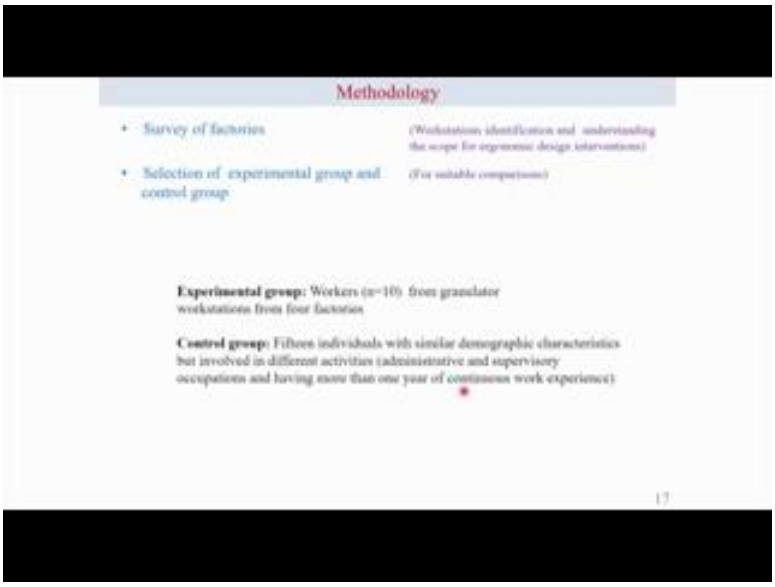

For this purpose, if we look at the methodology as reported in that paper, first survey of the factories workstation identification and understanding the scope for ergonomic design intervention. So, first for which factories that this study will be performed those factories are identified and scope of the study and design intervention are evaluated, based on that selection of experimental group and control group from those factories experimental groups and selection control group people are selected.

So, there are two groups; one group is experimental those are the workers, their number are 10. They are from granulator workstation from 4 factories and in control group there are 15 individuals with similar demographic characteristics, but they are involved in different activities they are involved in. So, this experimental group people they are actually the worker who are working in granulator workstation. On the other hand the control group or the other working people who are actually involved in other activities like supervisory activity, administrative job in the same work place or in the same factory with similar demographic characteristics.

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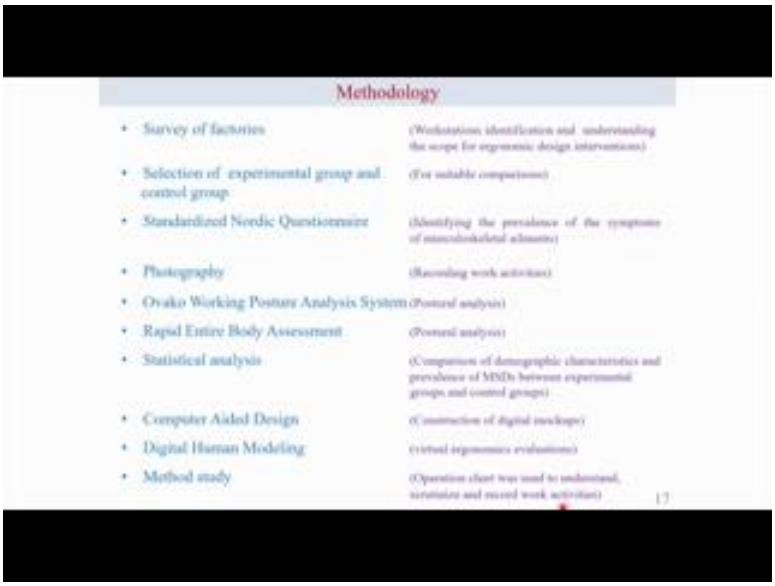

So, and they have one year of continuous work experience. Then standard Nordic questionnaire are used for identifying the symptoms of musculoskeletal ailments, then recording of the work activities are performed by photography as videography was not permitted by the factory management. So, only in this case still photograph were collected then posture of the workers, while they are performing various activities are evaluated using postural posture analysis tool like Ovako working posture analysis and rapid entire body assessment and statistical analysis which are performed which will be discussed later are.

So, comparison of demographic characteristic prevalence of musculoskeletal ailments between experimental group and control group, those things are statistical analyzed and then in this paper also computer aided design using CATIA software and digital human modeling from the digital human modeling module of that software are used for developing digital human models.

And method study the overall working methods were studied using operation chart, but to so, but time study was not possible in this particular research because factory management did not permit the whole day videography. So, operation chart was used to understand and scrutinize and record work activities.

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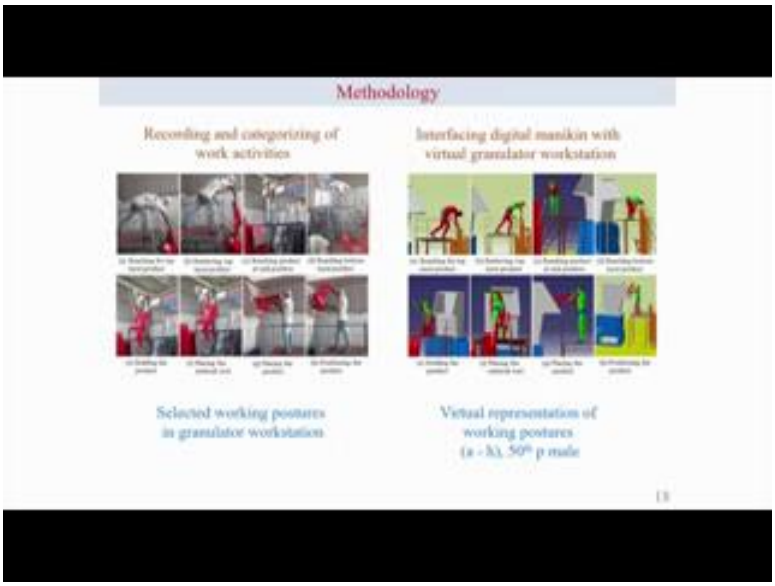

Now, from these two images it is apparent that this is the actual working condition of the workers, how they are doing these are the various steps a, b, c, d up to h. So, retrieving the chair then retrieving the top most products, gradually keeping it on the working surface, putting it on the slot of the granulator and ultimately pushing it inside the granulator, these are the various steps these are the key steps of the activities which is been performed by the worker in granulator workstation the same working posture based on that studying their body joint angle their posture are simulated in digital human modeling software.

Although the analysis was performed with 50th smaller average and larger digital human models, but in this particular diagram it is represented only with 50th percentile male see here two things is important to mention that all. So, how these digital human models are generated for anthropometric data as anthropometric data for Indian industrial workers was not readily available. So, for that purpose civilian anthropometric data are used for developing this digital human model and for comfort analysis for different body joints comfort range of motion are rendered using the comfort database available from various literature resources.

So, here we can see, that is color coating green and red, this red color is indicating that body parts are beyond the comfort range of movement and while that body parts are in green color, it indicates that that particular body parts or body joints is within comfort range of motion for that body joint. So, after simulation of the real work scenario and those key steps in that workstation work in process. So, you can find in many of the cases body parts are beyond the comfort range of motion.

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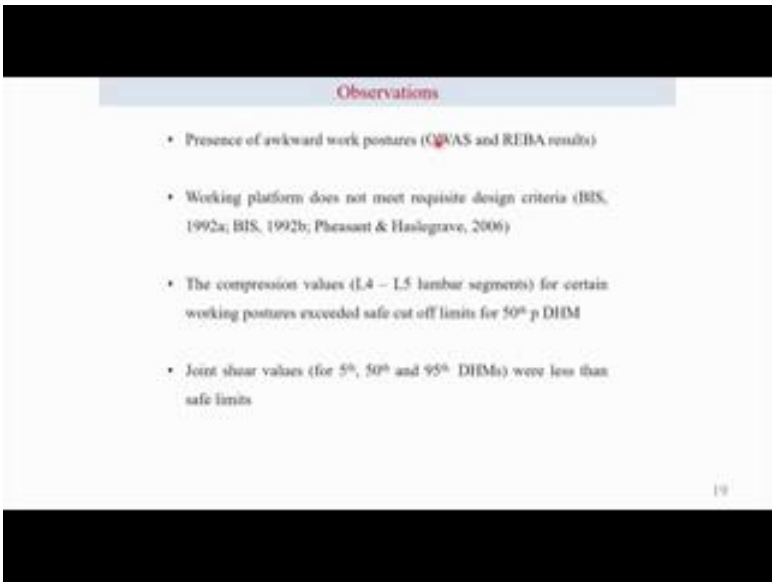

Then various observation which obtained from that research that prevalence of work awkward working posture based on the OWAS and REBA result then working platform does not meet the requisite design criteria as per various standards as mentioned here and also the reported literature the compression value L4 L5 inter vertebral decompression at the lumbar segment, this is L4 and L5 segment. So, it was found that posture inter vertebral, this pressure at L4 L5 level exceeded the safe cutoff limit for 50th percentile digital human model. But the joint shears force for 5th for all percentile digital human models; 5th, 50th and 95th percentile are within the safe limit.

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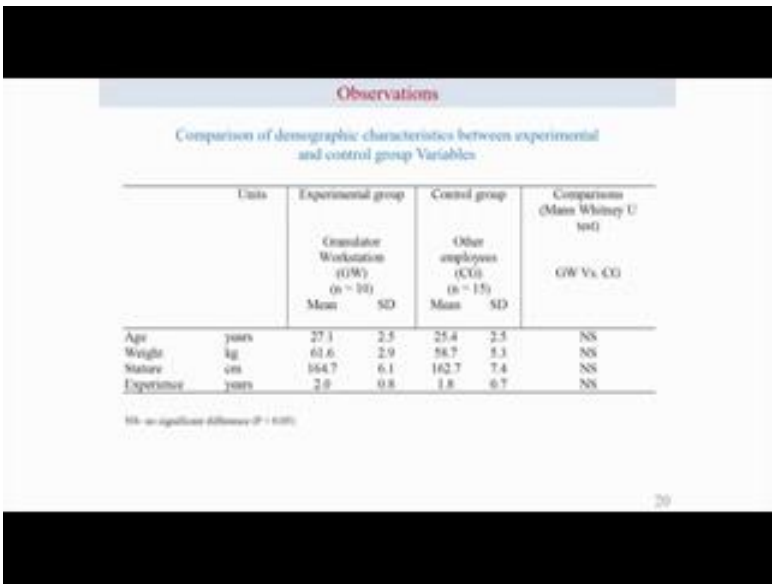

In this research paper from this table, it is the data of demographic characteristics of the worker with granular worker from granulator workstation that is the experimental group as well as other employees that is from the control group while you are comparing the

demographic data between these two groups, then we found in terms of age, weight, stature, experience there is no significant difference as per the Mann Whitney U test.

So, following the statistical evaluation we found that between these two groups, there is no significant difference means their demographic characteristic are almost same, but as we mentioned in previous slide, but they are suffering from body part discomfort. So, number of participants suffering from body part discomfort is tabulated here this are the number and this is expressed in percentage. So, this is the data of Nordic body part discomfort mapping.

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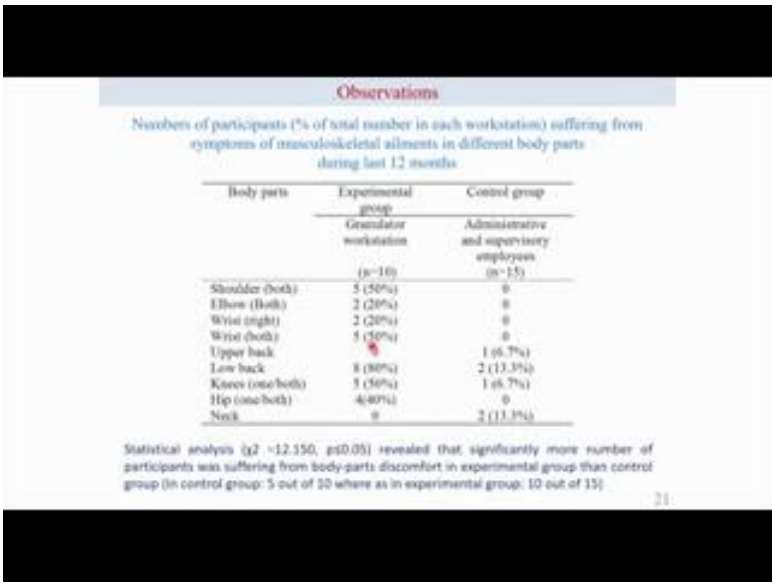

So, this is for the experimental group and this is the for the control group experimental group means people who are actually working in granulator workstation. So, if we look at various body parts and the occurrence of body part discomfort then occurrence of body part discomfort is actually higher in case of experimental group in comparison to control group.

The same thing was statistically tested using; it was found that suffering of the people of experimental group is significantly higher in comparison to control group in the previous slide as I mentioned. So, although there is no significant difference in terms of all insignificant and non-significant. So, although there is no difference in terms of demographic characteristic between this experimental group and control group, but suffering of this people is higher in this case, in terms of body part discomfort people in experimental group they are suffering more. So, from this it can be concluded that although the demographic characteristic of both the group is same, but suffering of this people is more in terms of body part discomfort. It indicates that obviously, there is some

reason in terms of their work habit, workstation design which is actually affecting their body part and they are suffering from pain.

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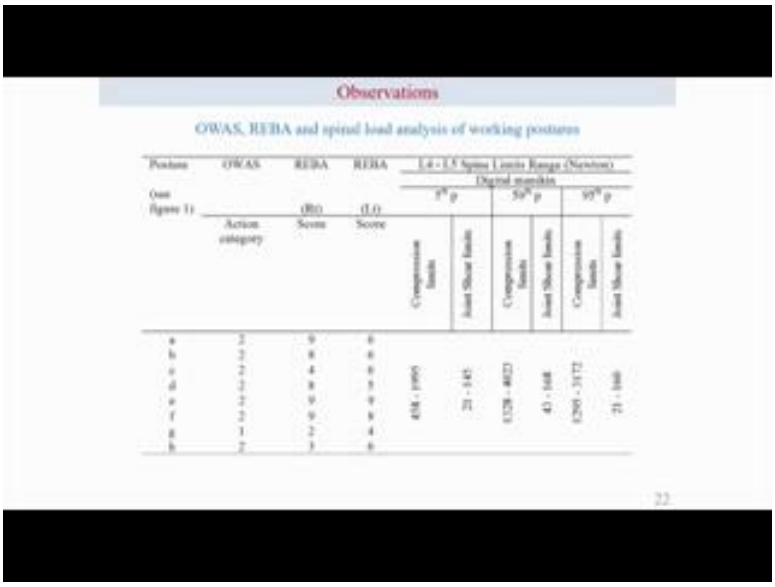

Next, this is the result of OWAS and REBA analysis. From this result you can see these are the action categories from OWAS analysis and these are the final or grand score from REBA analysis. For right side of the body and this is for the left side of the body and this is the L$ L5 minus final compression range expressed in Newton, this is from digital human modeling analysis for 5th percentile, 50th percentile and 95th percentile. This is the range of spinal compression force at the L4 L5 level compression force and this is the joint shear force for 5th percentile. Similarly, for 50th percentile this is the compression and this is the joint shear. So, the range is provided here.

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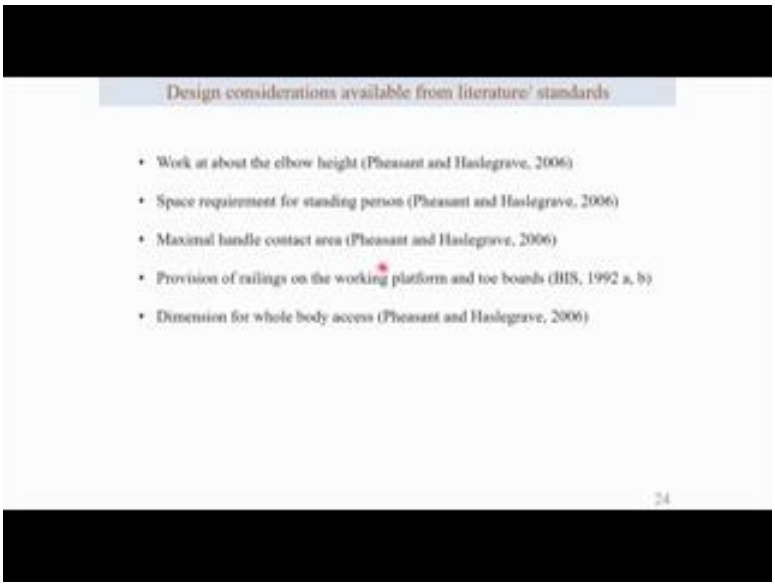

Design consideration available from the literature or standard. So, then the researchers studied various guidelines and standards available for this type of workstation design.

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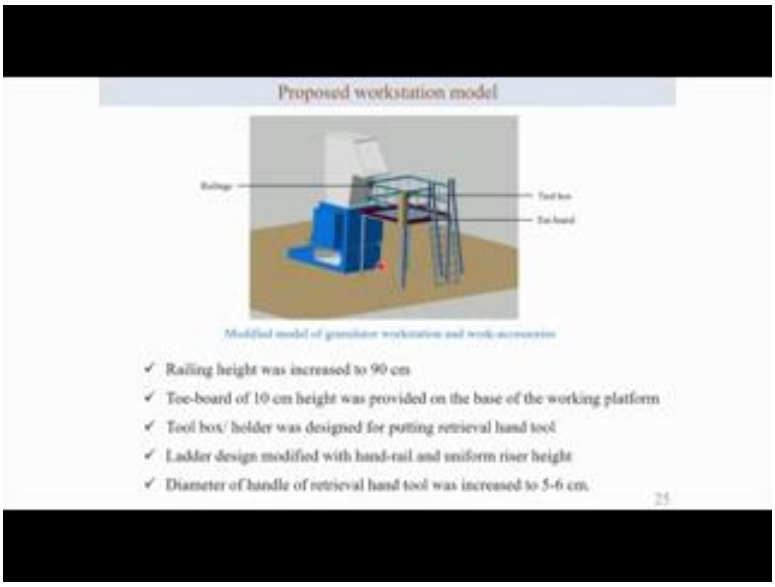

Based on that they redesigned that workstation not the main equipment that is the granulator workstation, but other accessories like stairs, then railing, then the tool box, whatever design modification was performed by the researchers this is mentioned here. So, railing height was increased by 90 centimeter toe board of 10 centimeter height was provided. This is the toe board and then there was no toolbox. Earlier the tool box was provided so that workers can keep the retrieving hand tool then railing was provided height of the railing was also enhanced. So, all this information is given here after modification of the workstation.

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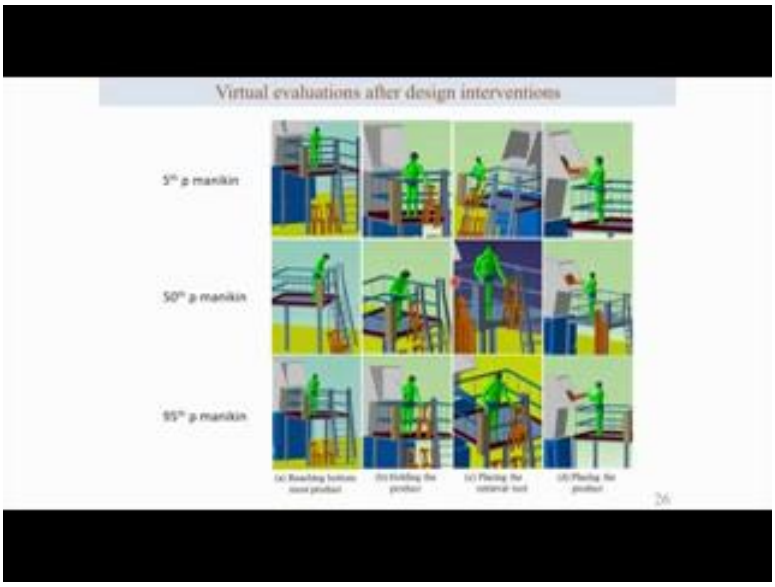

Then while those workers are doing their activity you can find this is for 5th percentile manikin, this is for 50th percentile, and this is for 95th percentile for all percentile manikins. Now, they can perform their activities comfortably all their body joint segments are in green color, mean body joint range of motion or range of that body part all the body joints in the particular postures are within the comfort range.

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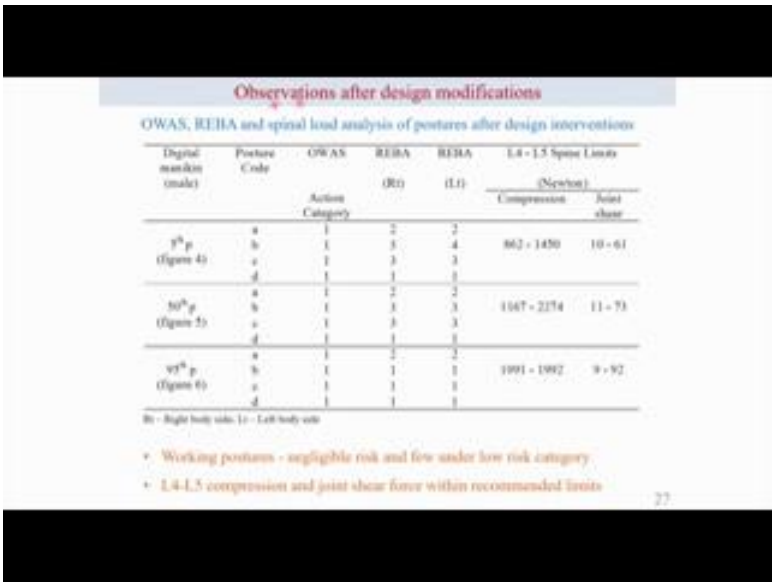

This is observation after design modification. So, while the redesign of that work accessories are done then it was observed that for all the per 3 percentile; 5th, 50th and 95th percentile worker the OWAS would was reduced, RULA and REBA also reduced. Similarly, the spinal compression and shearing forces for L4 L5 inter vertebral this that was also reduced. So, work in posture now there is negligible risk, few under low risk category L4 L5 compression and joint shear force within the recommended limits.

In this study, this was the methodology. So, what was observed from this study prevalence of awkward work posture following RULA and REBA analysis working platform does not meet the requisite design criteria as per various standards and literature the compression value L4 L5 lumbar segments for certain work posture exceeded the safe cut of limit for 50th percentile digital human model, but joint shears force for all 5th, 50th and 95th percentile models are less than the safe limit.

So, this is the result of demographic characteristic. So, this is for experimental group and this is for control group for experimental group while comparison was made between these two groups in terms of age, weight, stature and experience. Then we find that there is no significant difference following Mann Whitney U test, in all these cases difference is non-significant mean the demographic characteristics of these two groups are similar then this is a result for Nordic body part discomfort. In experimental group this is the

number of people suffering from body part discomfort for various body parts as mentioned here.

Similarly, this is the data for control group who are involved in administrative task as we mentioned earlier. So, between these two group whether there is any significant difference in terms of their suffering or in terms of the number of people suffering from various body parts discomfort statistical analysis using was performed and it revealed that significantly more number of participants are suffering from body part discomfort in experimental group than control group. Although, from this earlier slide it was evidence that although the demographic characteristics of the both groups are same, but the people in the experimental group they are suffering more in terms of body part discomfort.

It indicates that obviously, there is some problem with that work place may be in terms of workstation design or working posture or working method, then OWAS and REBA analysis as we mentioned that from OWAS and REBA analysis also there awkward posture was prevalent in that workstation. So, this is a result of OWAS analysis. So, action category as per OWAS analysis is for different. This a, b, c, d and up to h. This is the various postures as we described in this particular image.

So, these are the various postures for all this postures, this is the OWAS action category or all this 8 postures. This is the work action category similarly, these are these are the values for grand score as per REBA analysis for right side of the body and this is for left side of the body. Similarly, this is the data for 5th percentile, 50th percentile, 95th percentile, digital human models L4 L5 spinal limit range for compression force as well as for joint shear force.

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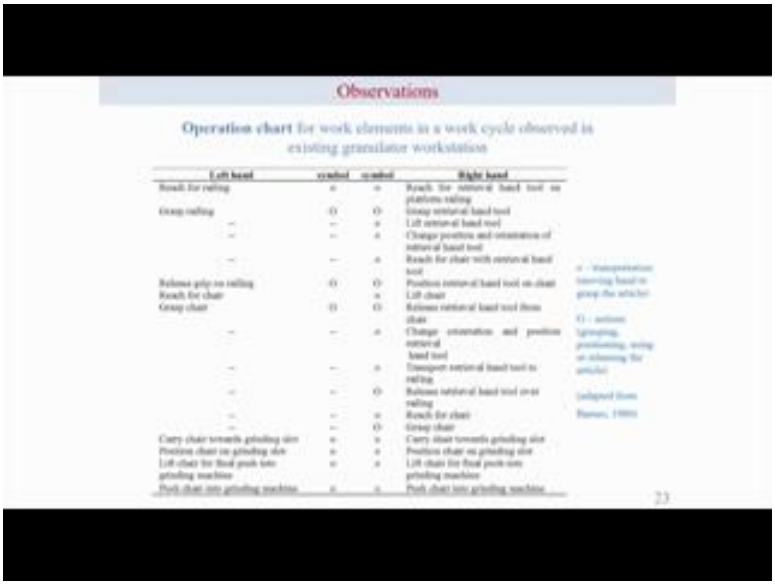

So, for the particular workstation also operation chart was used for studying the various work elements in a particular work cycle and this is the representation of that operation chart. So, where two symbols are used 0 for a small circle for transportation moving hands to grasp the object. So, small circle and large circle large circle is actually indicating the various types of actions. So, based on that operation chart is provided to show the various work elements in that in a particular work cycle in that workstation.

Design consideration available from literature. Those are also studied by the researcher and based on that they proposed the redesign of the work accessories and various work equipment's. The main workstation main machine that is a granulator workstation that was not modified, but other work accessories including the ladder railing tool box. This was modified earlier there was no tool box, but this tool box was added similarly. So, modification has been made in that workstation that is listed here, railing was provided and it was there also earlier and it has been increased up to 90 centimeter. It was earlier 70 centimeter, the toe board of 10 centimeter height was provided on the base of the working platform. So, this is the toe board then tool box was provided. So, that the worker can keep in the retrieved hand tool, then ladder was modified with hand rail and uniform riser height diameter of the handle of the retrieval hand tool was increased to 5 to 6 centimeter.

Following this modification, while the posture was evaluated using digital human modeling software, it was found that most of the body joints are now within comfort range and it is depicted in green color. Earlier before design modification many of the body parts or body joints are within beyond the comfort range and it was denoted by red color, but now after the modification of the work accessories it was found that people now can work comfortably because there, for this particular posture the body joints are within the comfort range of motion. So, for all 3 percentiles; 5th, 50th and 95th percentile it is found the same scenario.

So, after this design modification again while OWAS and REBA analysis and spinal compression force and shearing force were evaluated it was found that everything has been reduced. So, for all four postures after design modification the bending postures are eliminated and this four postures a, b, c, d are evaluated and this is the OWAS code for all these four postures OWAS codes was action category REBA code for right and left side of the body and this is the spinal compression. So, following this observation it was noticed that work working postures negligible and few under very low risk category and L4 L5 compression force and joint shear force is also within the recommended limit.

Then for this redesign workstation as it was not made in physical condition or it prototype was not made. So, the work method used or studied using operation chart work elements. In a particular work cycle that work cycle that this is the anticipated work cycle. So, after this modification how these workers will do their activities based on that based anticipating those activities. This is the operation chart and from this operation chart operation chart, if we compare this operation chart with the earlier one before the design modification then we can identify that operation chart indicated this operation chart indicated that there is reduced number of work elements in comparison to the earlier case means before design modification. So, design modification ultimately lead to number of reduction of the work elements in a particular work cycle.

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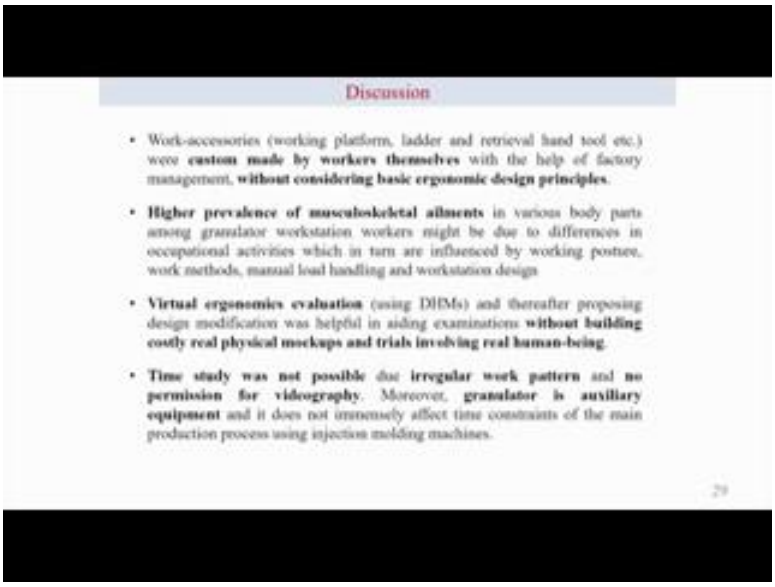

So, in the research paper they Sanjog et al. discussed few important points. So, one of those points are work accessories that is work platform, working platform ladder, retrieval hand tools etcetera are custom made by the workers themselves with the help of factory management without considering the basic ergonomic principle. So, work accessories I have mentioned here, all these things were actually made by the worker themselves who does not have any ergonomic design knowledge. So, this situation ultimately leads to higher prevalence of musculoskeletal ailments among various body parts of those granulator workstation workers.

So, this might be due to differences in the occupational activities in which in turn influenced the working posture work methods manual load handling and workstation design. So, from this study it was clearly understood that virtual ergonomic evaluation using the digital human model and thereafter proposing design modification is really

helpful in aiding examinations without building costly real physical prototype or physical mock up.

So, in this research it was clearly showed that without making the actual physical prototype only through virtual cad model and digital human modeling evaluation. We can identify the problems and we can also provide the solution for that. So, time study was not possible in this particular research because as I mentioned earlier also, videography was not permitted and there was irregular work pattern and no pattern moreover granulator is auxiliary equipment and it does not immensely affect the actual main production system by the injection molding machine.

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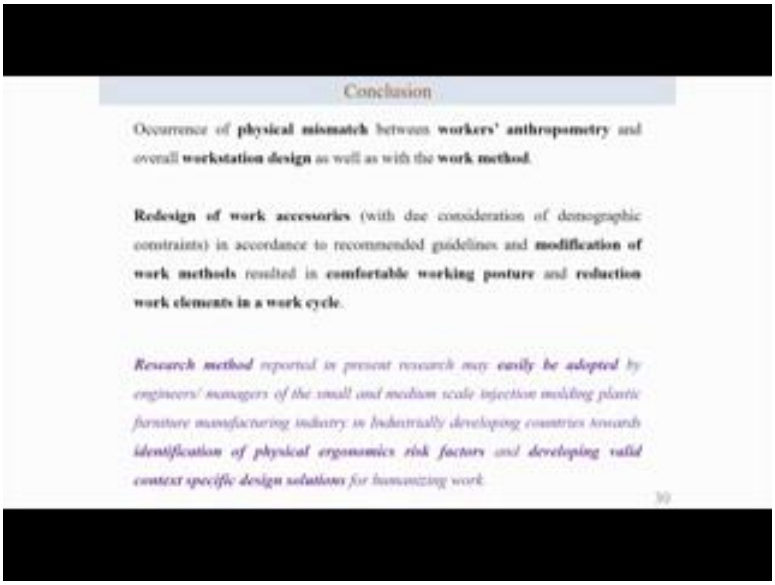

So, it was concluded that occurrence of physical mismatch between workers anthropometry and overall workstation design as well as work method was prevalent in that workstation.

Redesign of the work accessories due to consideration of demographic constraints in accordance with the recommended guidelines and modified work method reduce resulted in comfortable working posture. So, while workstation accessories are redesigned as per various guidelines and standard proposed by various researchers and various standard bodies, if we can redesign the work accessories as per those recommendations and guideline and we and modification of the work methods then it will ultimately lead to comfortable working posture and reduction of work elements in a work cycle.

So, research method reported in the present research may be easily adopted by the engineers or managers of a small medium scale injection molding plastic furniture manufacturing industry. In industrially developing countries towards identification of

physical ergonomics risk factors and developing valid context specific design solution for humanizing work. So, in this is paper was very a clearly shown that how digital human modeling software can be used for industrial work place modification design modification without preparing the actual prototype.

Based on this, what is possible? So, based on this evaluation while researchers or that factory management will find that yes, this type of modification is possible and it will improve their productivity and the safety or workers well being then the actual prototype can be made and implemented.

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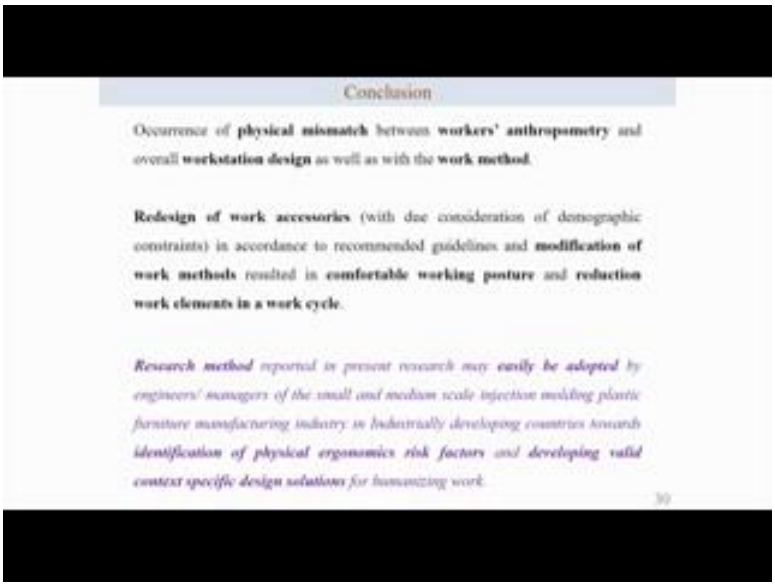

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So, these are the list of references which has been used in various slides. So, all of you should go through these references for better understanding of those papers and also you

can go through there are. So, many other papers published in this particular domain that is the application of digital human modeling, in various industry specific workstations for knowing more in for this particular field because every year there are so many conferences are going on, there are conference papers proceeding as well as, many other journal papers.

So, if you go through all these papers then you will get much more clear idea about how this digital human modeling software are presently being used in industrial software workstation for improvement of ergonomic conditions.

Thank you.