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Anthropometry and Its Significance in Safer Agricultural Activities- A Review Article

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ABSTRACT:
Ever since from the ancient civilization, the human body dimensions have been measured and used for numerous reasons and applications. Creation of figurative arts, criminology, medical science, industrial situations, product design, automotive and in many more sectors these physical body dimensions are reported in numerous literatures and were summarized in brief in this paper.
Implementation of these anthropometric data in different farming/agricultural situations is reviewed in the present article. Agricultural sector is considered to be one of the most hazardous working places in the world today. The current paper mainly focuses on the applications of human factors, physical body dimensions in the regular agricultural practices in the developing and under developed countries and its impact on farmer comfort, ease of farming operations and improvement in agricultural productivity in terms of quality and quantity. The utilization of these body dimensions in various agricultural activities and thus, improving the operating comfort are enlisted, which further can be used in the design of farm tools, implements and equipments.
Keywords: Anthropometry, Ergonomics, Human factors, Agriculture

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I. INTRODUCTION:

Since from the ancient civilization, the human body dimensions have been measured and used for numerous reasons. The body measurements were mostly used in creating human figurative arts, paintings and sculptures depicting the realistic human pictures, paints and models [1]. Further, the data of human body measurements in seventeenth century coined as Anthropometria [2] by German physician Johann Sigismund Elsholtz. It is referred to a method of measuring the living human body parts in establishing the individual sizes at different ages, thus differentiating the human populations relative to one another. French savant, Alphonse Bertillon called it as Physical anthropometry in the scientific method of criminal investigation [3, 4]. He was the first forensic expert to use the anthropometric data in recording the criminal records. During the eighteenth century, the data of human body measurements was used for evaluating the healthy physique of slaves and assessment of physical wellbeing in the recruitment for armed forces by measuring their stature, different body part dimensions, body weight, body shape and muscle strengths or working capacity. Further, in nineteenth century, the data of human body measurements was extended in the medical practices to explore the human body for scientific and medical purposes in identifying the correlation between human body and various diseases. It became a new tool in clinical practices and taxonomy due to increase in public health cautiousness. Today, in medical science and practices anthropometric data is being used in broad spectrum in the areas like nutrition science, cosmetology and aging, obesity studies, sports science, epidemiology, scientific dieting, physical therapy, exercise physiology, surgery and dentistry [5-8].

In engineering discipline, anthropometry influences in a wide range of applications in industrial sectors, process industries, product design, garment industries, automotive, aerospace and building design.

Safety in industrial workplace mainly depends on comfortable fit between the working environment, operating tools and the worker. Industry related work also involves the material handling tasks like physical lifting, push-pull loadings and repetitive body movements. The crucial requirement in product or process industries is to design the workstation and equipments suitable for the employed industrial workers. Often, the bad workspace design and awkward working postures in industrial sector have resulted in body fatigue and work related injuries, thus affecting the overall work efficiency and productivity [9-11]. Work related musculoskeletal injuries thus represent one of the leading reasons of occupational injuries in various industries [12]. The key reason for this can be correlated to not proper use of human body dimensions and ergonomic principles in designing the industrial workplace [13]. Use of proper anthropometric data and implementation of systematic ergonomic guidelines often resulted in improved working efficiencies, human comfort and increased productivity. Many researchers have published anthropometric data useful for performing the industrial tasks [14 -17]. Figure 1 below illustrates some of the typical applications of anthropometric data in industrial scenarios like design of material handling process, computer workplace design, convenient working height in standing posture, side reach tasks and over head tasks.

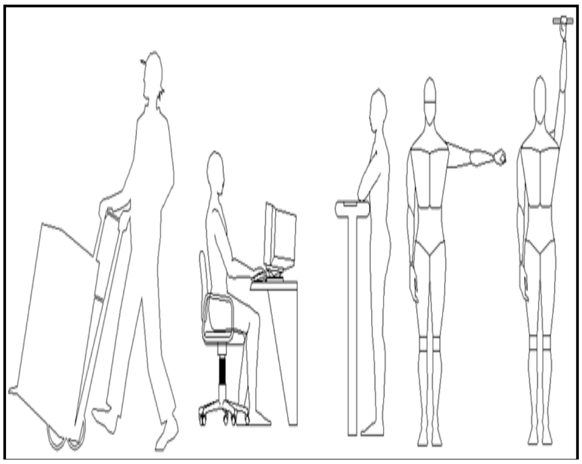

Fig.1. Typical purpose of anthropometric data in designing industrial applications

A product in consumer market is something that satisfies a want or need, which is the result of an act or process and produced by laborious work or effort. Most of the products interact with humans in one or the other way. Starting with simple safety pin to mobile phones, shoes, kitchen utensils, TV, refrigerator, FMCGs, furniture and automobiles can be considered as a product. The knowledge of human body dimensions is regularly used in product design to validate whether the designed product is fitting to its user or not. The anthropometric data provides the range of target users to the designers-manufacturers and fixes the accurate product dimensions and features [18]. It is recorded that many products failure in the past is the result of not using proper anthropometric data of a particular geographical region or designing it for average value or designers considering their own body dimensions in developing a product [19, 20]. Design intent, functionality, quality and price are the basic elements in any product design. An ergonomically designed product considering the user body data apart from above elements, also improves product comfortless, safety, product image and attractiveness [21-24]. The proper inclusion of these elements in design creates products that are pleasant to use and also enhance the quality of life.

In the design of clothing, designers, in most of the situations, are not familiar with the principles and application of anthropometry in apparel industries. Clothing which are loose can get struck during body movement and may cause accidents. Similarly the tight clothing may restrict the body movements and muscle activities during work. Tight clothing reported to cause restricted joint and body movements at chest, shoulder, hip and lumbar spine regions [25, 26]. This situation is usually seen in ready to wear type of clothing, where large numbers of customers are dissatisfied by the degree of fit established in its design. Hence in designing comfortable fit clothing for a population of particular region, it is desirable to use the body shape, size and dimensions of the target population. In figure 2, an example related design of comfort clothing based on the anthropometric data of the end user is illustrated.

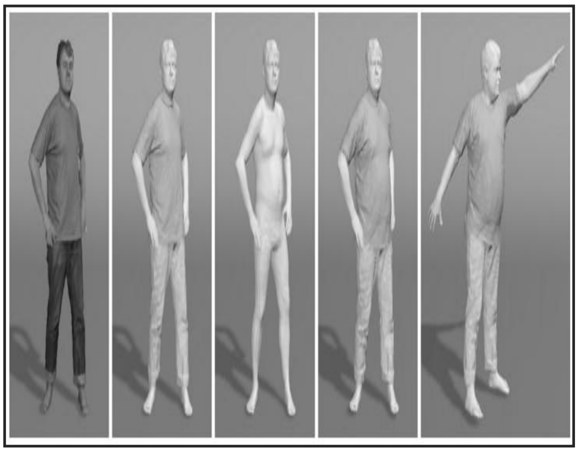

Fig.2. Anthropometry applied in clothing and fashion designs

A customer expectation for automobile and aerospace sector in terms of comfort continues to rise. In designing the automobile, it is necessary to consider wide range of body dimensions of both male and female drivers as well as passengers. Accurate knowledge of driving posture, passenger's way of seating is essential in designing automobile work space. Ergonomics in automobile and use of anthropometric data helps in analyzing driver-passenger comfort, inside and outside vision, design of display and control modules, physical loading during driving, reach to actuating elements like pedal, braking and clutches as shown in figure 3. From various studies it is observed that sitting for prolonged intervals in vehicles has direct impact on increased discomfort for drivers and passengers. This discomfort in vehicle ride is related to body pain, neck pain, tiredness, reduced blood circulation in legs and numbness which can lead to musculoskeletal disorders [27, 28]. In aviation industries too, precise human body dimensions are needed in designing the aircraft and its structures, without compromising individual comfort and safety. Many researchers have published anthropometric data in the design of aircraft cockpit, aviator's workplace and passenger's space to improve the operator and passenger comfort in terms of visibility, reach, postures, upper limb movements and physical loading [29-35].

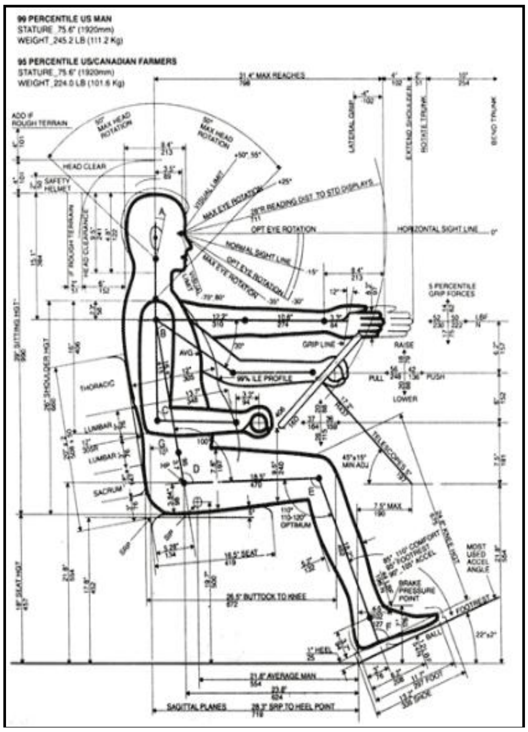

Fig.3. Anthropometric illustration for automobile driver posture and position

Human body dimensions inspire and play an important role in the design and dimensions of the buildings. The building regulations offer a wide range of standards and solutions for designing buildings to fit the human body. The dimensions of stairs, lifts, ramps, balcony, ceiling height, doorways, bedrooms and bathrooms must have enough space for easy maneuverability in and around the buildings, thus signifying that science of human proportions as the fundamental principle in building and architectural designs [36-38]. The result of applying human factors and ergonomics in building and architectural designs aims to enhance occupant's safety, health, comfort, productivity and satisfaction [39]. Architects and building designers must consider human dimensions while designing an individual body motions and participation in different activities in any building or industry. Figure 4 shows an example signifying the importance of anthropometry and its applications in the design of residential building plans in arriving various building parameters like width and height of stairs, dimension sizes of living room, bed room, bath rooms, kitchen, balcony and study room for easy maneuverability. Further, the same methodology can also be utilized in designing the building elevations by considering the body parameters like stature, shoulder height, eye height, etc in deciding the dimensions of door openings, interior slab height, bathroom clearance height, kitchen utility and working space etc.

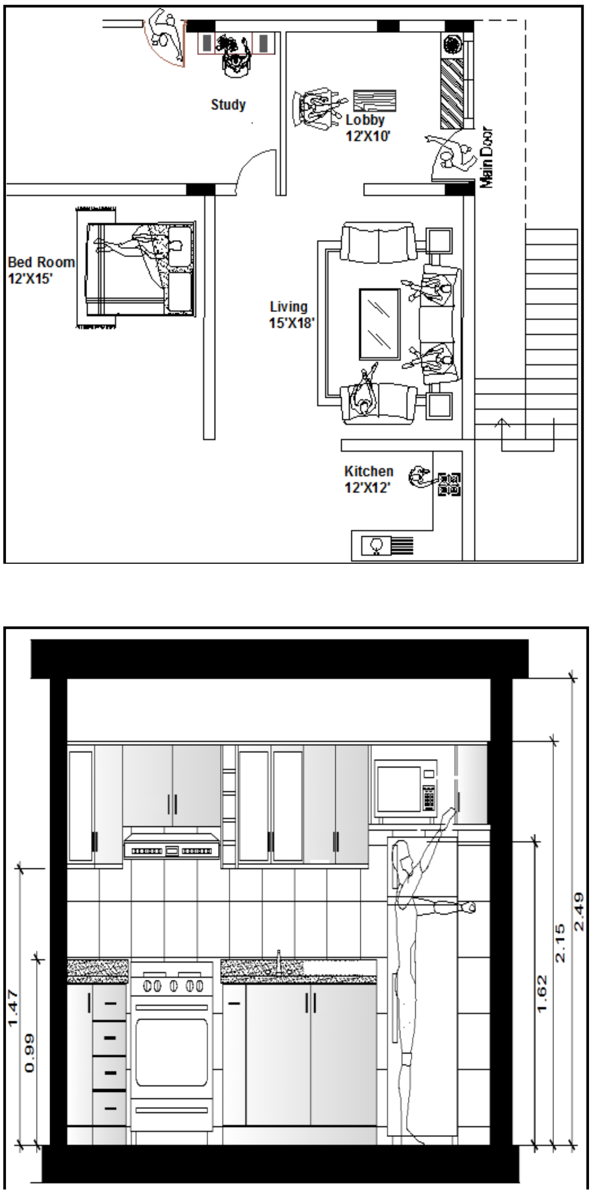

Fig.4. Application of anthropometric data in designing residential plan and elevation

II. ANTHROPOMETRY IN AGRICULTURE:

After recognizing the consequences of anthropometry and human factors in the various above mentioned sectors, this article focuses on its impact and usefulness on the various agricultural scenarios, which is considered to be the most dangerous occupation of the world today. Agriculture is the process of cultivating the plants to provide food, fiber, medicinal plants and other by products to sustain and improve quality of life. It provides occupation to the majority of rural-urban population and food security to the people all around the world. Over one third workers of the world are engaged in the agricultural sector, making it the second largest job providing sector after service industries. Development of agricultural sector plays a critical role in the overall development of a nation by reducing poverty and food insecurity. The main concern in today's agricultural process in most of the developing and under developed countries are reduced quality and quantity of nutrition in the food, scarcity of water, soil fertility, small land holdings, tremendous expenditure with less return behind farming, increased population, urbanization, drastic climatic change, natural and human induced hazards, pollution and its ill effects [40, 41].

The current paper mainly focuses on the applications of human factors, physical body dimensions in the regular agricultural practices in the developing and under developed countries and its impact on farmer comfort, ease of farming operations and improvement in agricultural productivity in terms of quality and quantity. Usually, the farm implements that do not fit the farmer's physical characteristics can cause uneasiness in its usage and fatigue resulting in lower productivity and a higher incidence of agricultural accidents and injuries. The effects of anthropometry in various farming stages like soil preparation, seed sowing, irrigation, pre and post harvesting are reviewed.

1.1 Soil Preparation:

Soil preparation is the first fundamental stage in the process of growing a crop. The main purpose of soil preparation is to loosen the soil to prepare a firm, weed free seed bed for quick germination of seeds. The soil preparation phase destroys weed, increases decomposition process of previously leftover agricultural residues, assists in proper soil aeration and water distribution-absorbing capacity across the farming land and supports the growth of earthworms and microbes in enriching the fertility of soil. The three main steps in soil preparation are ploughing, leveling and manuring. Ploughing is the process of digging and loosening the soil, thus increasing soil aeration and making plant roots to easily penetrate between the soil. Apart from loosening soil it also helps in bringing back the deep held soil nutrients to the top and facilitates the removal of infectious pathogens and insects to the top. Uneven soil surface after ploughing is leveled in next stage, which evenly distributes the soil all along the cultivating area. Soil fertility and quality is increased by adding manure before initiating the seed sowing process.

In most of the developing and under developed countries, farmers having small holdings use manually operated tools-equipments or animal driven implements to accomplish soil preparation and ploughing operations, which are usually developed by individual village craftsmen and because of their lack of ergonomic knowledge, they are not in a position to consider anthropometry when manufacturing the ploughs [42]. It is estimated, nearly 160 man-hours required per ha of land preparation. In case animal driven plough, full body weight is applied on the plough to increase the overall ploughing efficiency. Major work-related risk factors include longer static positioning, awkward bending, kneeling and often subjected to vibrations. Anthropometric data like hand length, breadth, grip diameter, arm reach from wall, forward grip reach, push-pull strength, body weight are utilized in the design of various hand operated soil preparing tools and equipments [43]. The position of center of gravity in different body postures during various soil preparation and ploughing process is also another most important parameter to be considered in soil preparation stage. A change in center of gravity may result in short-term discomfort in different body parts, which may be due to frequent change in center of gravity while working. To reduce body discomfort and work related injuries, the optimum location of center of gravity is between the plough and the person operating the plough.

The above data thus can be utilized in determining the size, shape and form of tools, equipments and machinery in improving the comfort for human use, thus improving operating efficiency and increasing agricultural productivity in soil preparation or ploughing operations.

1.2 Seed sowing:

Seeds are the main element in an agricultural activity, without which it is impossible to achieve any agro based yield. The very next stage after soil preparation is sowing; where in the good quality of seeds are selected and spread uniformly in the field to avoid overcrowding of crops. It includes, placing the seeds at desired depth and spacing by providing proper soil compaction over the seeds, thus allowing proper sun light, water and manure to reach the desired location of the seed to achieve optimum yield [44]. Broadcasting, line sowing, dibbling, transplanting, planting and plough sowing are the common methods employed in case small land holdings. In small agricultural lands, dibbling and metering is done either by using stick or by hands, which results in uneven seed distribution in both inter and intra rows. These manual methods of sowing using hands and animal driven plough often results in excessive muscle loadings, regular posture changes, awkward body positions, constant exposure to static and dynamic forces due to mismatch between equipments being used and user anthropometric data [45]. In the design of these sowing tools and equipments ergonomically, appropriate anthropometric and strength data is required to increase working comfort, efficiency and productivity [46]. Figure 5 below illustrates an example of conventional method of maize seed sowing method like manual sit-bend hand sowing and walk-bend hand sowing, which is unsafe posture and results in work related injuries in the farmer communities. A simple seed sowing equipment, designed based on the anthropometric data of the agriculture worker is safe in terms of its usability and comfort. The tool allows farmer to sow the seed in comfort standing and walking posture without either bending forward or sitting.

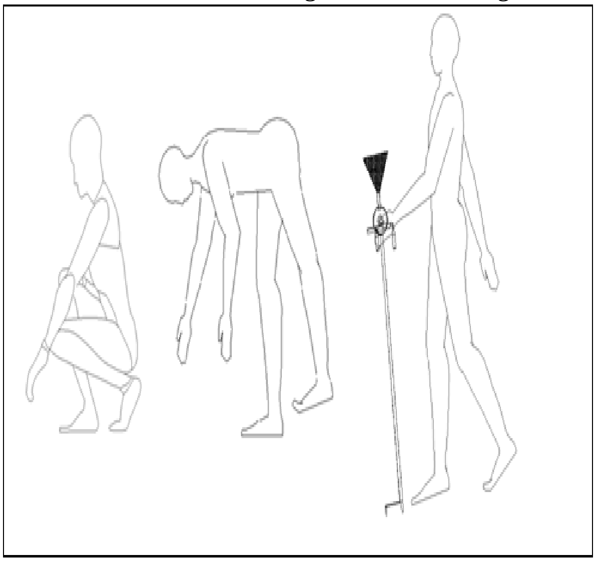

Fig.5. Manual Method Ergonomically designed

1.3 Irrigation:

Water is an important constituent in agricultural sector and plays a critical role in achieving overall food security. Effective utilization of water in farming process influence the entire growth process from bed preparation, seed germination, plant root growth, efficient nutrient utilization, hence increasing agricultural yield and quality. Nearly, 70% of water drawn from rivers and underground water is consumed in agriculture and in its related areas [47]. The irrigation process helps in the distribution of controlled amount of water to plants at required period. It is an artificial supply of water to the soil to enhance plant growth through various systems of pumps, tubes, channels and sprayers. Farmers having low and medium land holdings usually carry the manual method, surface irrigation, drip irrigation or sometime with sprinklers for irrigating the farm land. The physical activities like lifting, manually creating channels for water flow in case of surface irrigation, pushing or pulling of manual sprayers, handling of knobs, levers and handles of irrigation system often observed in such farming process. For hand operated sprayers, ergonomic consideration in design is a key parameter to be implemented for its effective and safe operation with reduced work related injuries [48].

1.4 Harvesting:

Harvesting phase in agriculture starts with gathering matured crops from field, cutting/separating the crop/grains from plants, drying the crops/grains, cleaning the crop and followed by packaging/bagging the crops. Traditionally, farmers belonging to low and marginal sectors follow manual methods of harvesting, which is moderately heavy in task and makes agricultural workers to implement many awkward body postures and positions, which further might result in many MSDs [49]. Study of anthropometry, work-motion-posture study in harvesting has showed minimized work related risks in agricultural scenario [50]. Hence it is vital to considering these data region wise in order to properly accommodate the users to arrive at safer harvesting tasks with minimized work related injuries/disorders [51]. Many human physical body parameters/dimensions pertaining to the man-machine interfaces in harvesting stage can be effectively and efficiently be utilized in finalizing the designs. Several studies and researches related to anthropometry and its good impact on harvesting phases were reported by many researchers [52-56].
Following table lists the applications of various anthropometric data in different agricultural phases/designs, which needs to be considered in the development of safer and comfortable working conditions for the farmers.

Table 2.1 Application of anthropometric data in different agricultural situations

S.No	Anthropometric Dimensions	Usefulness and applications in agriculture
1	Height	• To design proper handle height. It should be designed ensuring that the operator is standing erect while operating. • Design of controls, display positions of equipments. • Handle height for animal driven plough. • Handle of manual, semi automatic or fully automatic weeder. • Handle of seed sowing equipment. • Design of Lever operated knapsack (LOK) sprayer. • Design of power operated thresher, feeding chute height. • Lift studies and analysis in force applications.
2	Eye height, standing	
3	Shoulder height, standing	
4	Elbow height, standing	
5	Waist height, standing	
6	Knuckle height, standing	
7	Finger tip height, standing	
8	Sitting height	• Design of seating system for tractors, power tiller, planter. • Work place layout design, working area space designs. • Design of lever, push-pull buttons, control panels, display devices from the sitting position. • Design of display systems, visual observation systems. • Clearance between seat and steering system or inner portion of working table. • Design of sitting mechanisms for thresher, cutter, harvester, plant feeder. • Steering wheel position and orientation.
9	Sitting eye height	
10	Sitting shoulder height	
11	Sitting elbow height	
12	Sitting thigh height	
13	Sitting knee height	
14	Sitting popliteal height	
15	Shoulder elbow length	
16	Elbow fingertip length	
17	Overhead grip reach, sitting	• Control buttons, levers position to be designed within the operator's reach. • Workplace, working space design and design of controls. • Lift, pick-up studies, workplace layout designs • Design of gear levers, position control levers, various pull type control levers.
18	Overhead grip reach, standing	
19	Forward grip reach, standing	
20	Arm length, vertical	
21	Downward grip reach	
22	Span	
23	Hand length	• To design Handle grip diameter for Hand Tools and Manually Operated Equipment • To design Handle length for Hand Tools and Manually Operated Equipments • To design hand operating buttons, emergency knobs diameters for push-pull operations. Design of hand gloves. • To design foot operated pedals, knobs, buttons or levers. Design of safety shoes. • Design of hand operated levers, braking system, clutch mechanisms, sprayer triggers.
24	Hand breadth	
25	Foot length	
26	Foot breadth	
27	Hand grip inside diameter (Max.)	
28	Hand grip strength (Kg)	
29	Weight	• Strength analysis of various elements where full body weight is acting like on seat, platform for thresher, harvester, plough etc. • Load carrying capacity of individual farm worker. • Push-pull strength for operating an equipments, • Foot/leg strength for operating a pedal or lever. • Cranking torque and steering strength for cutters, steering wheels and manual crusher.

III. DISCUSSION:

Anthropometry is integral part of the design where humans are involved. It plays a significant role in the design and development of products that are used by humans in their day-today life [57]. Anthropometric data gives immense amount of information to the designers and manufacturers for the development of ergonomically improved products which are used in a particular geographical region. Ergonomically designed equipments/products improve the human operating efficiencies and comforts during its operation [58, 59]. Hence, design for human comfort (DFHC) is the key area which needs to be addressed by every designer in today's product development environment as there is enormous amount of variations in body dimensions among individuals who are using those products [60, 61]. Anthropometry is engaged to create designs for human use in numerous areas like forensic, garment, FMCG products, architecture, automotive etc.

In agricultural scenario, interventions of anthropometry and hence the ergonomic principles in design reduces labor drudgery, enhances operating efficiency and hence encourages to build safer working conditions. To ensure these, it is necessary to apply the human physical dimensions in all the farming related activities. Since the body dimensions of one region varies significantly with the other, it is also necessary to develop region specific anthropometric data before implementing it in that particular area. Depending on the requirement and significance, various percentile values of these anthropometric data are being utilized in the design of different farm tool or equipment parameters. For example, 95^{th} percentile of hand breadth dimension is used in finalizing handle length, where as 5^{th} percentile value of inside grip diameter is used in arriving at the size of handle diameter.

IV. CONCLUSION:

Based on the literatures and the articles studied in the present review, it was observed that human physical dimensions or their anthropometric data has a wide scope of application in numerous areas where human-machine-workplace interactions are often involved. A detailed discussion on the significance of these data in agricultural related phases and its related activities were mentioned in the article. The applications of these data in the design of various agricultural related tools/equipments/implements and their important parameters were summarized. Hence, the collection of region specific anthropometric data is required to design farm implements/tools to evaluate them ergonomically. The data further also helps in achieving the improvements in tools/equipments/implements design which are being used successfully in other parts of the country.

REFERENCES:

[1]. Vangara Shanmukhi Varalakshmi , Sanna Mehmood , Patnaik V.V. Gopichand , Dhananjay Kumar, "Anthropometry: As A Tool in Learning Living Anatomy", Sch. J. App. Med. Sci., 5(5C):1938-1944, 2017

[2]. S. J. Ulijaszek and C. G. N. Mascie, Taylor, "Anthropometry: The Individual and the Population", Cambridge University Press,Cambridge, UK, 2005.

[3]. George Pavlich, "The subjects of criminal identification", Punishment and Society, 1462-4745; Vol 11(2): 171–190, 2016.

[4]. Cole, Simon A. "Suspect identities: A history of fingerprinting and criminal identification". Cambridge, MA: Harvard University Press, 2001.

[5]. Nevin Utkualp and Ilker Ercan "Anthropometric Measurements Usage in Medical Sciences", Biomed Res Int. 2015: 404261.

[6]. Pentapati K. Chakravarthy, Gowtham Suresh, Deepika Chenna and Vijay Chenna "Relationship between anthropometric measures and dental caries among adolescent National Cadets Corps of Udupi district, south India", J Nat Sci Biol Med. 4(1): Jan-Jun 2013 : 167–170.

[7]. Vishaw Gaurav and Amandeep Singh, "Anthropometric characteristics of Indian volleyball players in relation to their performance level", Turkish Journal of Sport and Exercise - Volume: 16 - Issue: 1 2014: 87-89.

[8]. Elisabeth S. Hastings, Roberta H. Anding, and Amy B. Middleman "Correlation of Anthropometric Measures Among Obese and Severely Obese Adolescents and Young Adults: Clinical Research Report", ICAN: Infant, Child, & Adolescent Nutrition, Vol 3(3), 2011: 171-174.

[9]. Denis, D. St-Vincent, M. Imbeau, D. Jette C. and Nastasia I. "Intervention practices in musculoskeletal disorder prevention: A critical literature review", Applied Ergonomics, pp. 1-14, 2008.

[10]. Robertson, M. M. Ciriello, V. M. Garabet , "Office ergonomics training and a sit-stand workstation: Effects on musculoskeletal and visual symptoms and performance of office workers", Applied Ergonomics, pp. 73-85, 2013.

[11]. Garcia-Herrero, S. Mariscal, M. Garcia-Rodriguez, J. and Ritzel. D. "Working conditions, psychological / physical symptoms and occupational accidents", Baysean network models, Safety Science, pp. 1760-1774, 2012.

[12]. NurAiza Z. and Rampal, K.G. "Musculoskeletal problems and its influencing factors among automobile factory workers". Community Health Journal, 12(1). ISSN 1675-1663, 1999

[13]. Ashraf A.Shikdar and Naseem M.Sawaqed , "Worker productivity, and occupational health

and safety issues in selected industries", Computers & Industrial Engineering, Volume 45, Issue 4, December 2003, Pages 563-572

[14]. L.P.Gite and B.G.Yadav, "Anthropometric survey for agricultural machinery design: An Indian case study" , Applied Ergonomics, Volume 20, Issue 3, September 1989, 191-196,

[15]. Arunesh Chandra, Pankaj Chandna and Surinder Deswal, "Analysis of Hand Anthropometric Dimensions of Male Industrial Workers of Haryana State", International Journal of Engineering (IJE), Volume (5) : Issue (3) : 2011

[16]. Pankaj Chandna , Surinder Deswal and Arunesh Chandra, An anthropometric survey of industrial workers of the northern region of India, International Journal of Industrial and Systems Engineering, 6(1), pp. 110–128, 2010

[17]. Deepak Kumar Kushwaha and Prasad V.Kane, "Ergonomic assessment and workstation design of shipping crane cabin in steel industry", International Journal of Industrial Ergonomics, Volume 52, March 2016, Pages 29-39.

[18]. Ferguson Taylor, Greene Melissa, Repetti Frank, Lewis Kemper and Behdad Sara, "Combining Anthropometric Data and Consumer Review Content to Inform Design for Human Variability" Proceedings of the ASME, International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, 2015.

[19]. Manuela Quaresma, Anamaria de Moraes, Vânia Maria Batalha Cardoso, "Some Causes of Errors Using Anthropometric Data when Designing Products and Workstations", Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 44, 33: 323-326, 2000.

[20]. Jean-Claude Sagot, Vale´rie Gouin and Samuel Gomes, "Ergonomics in product design: safety factor", Safety Science 41;137–154, 2003

[21]. Vink, P., Koningsveld, E. A. and Molenbroek, J. F."Positive outcomes of participatory ergonomics in terms of greater comfort and higher productivity". Applied Ergonomics, 37(4), 537-546, 2006.

[22]. Jordan, P.W. "Human factors for pleasure in product use". Applied Ergonomics, 29 (1), 25-33, 1998.

[23]. Nagamachi, M. "Kansei engineering: a new ergonomic consumer oriented technology for product development". International Journal of Industrial Ergonomics, 15(1), 3-11, 1995

[24]. Park, J. and Han, S. H. "A fuzzy rule-based approach to modeling affective user satisfaction towards office chair design". International Journal of Industrial Ergonomics, 34(1), 31-47, 2004.

[25]. Yoo IG and Yoo WG, "Effects of wearing of tight jeans of lumbar and hip movement during trunk Flexion", J. Phys. Ther. Sci, 24 (8), 659-661, 2012

[26]. Eungpinichpong W, Buttagat V, Areeudomwong P, Pramodhyakul N, Swangnetr M, Kaber D and Puntumetakul R, "Effects of restrictive clothing on lumbar range of motion and trunk muscle activity in young adult worker manual material handling", Appl Ergon,44(6),1024-1032, 2013.

[27]. M. Kolich, "Using failure mode and effects analysis to design a comfortable automotive driver seat", Appl. Ergon., vol. 45, no. 4, pp. 1087–1096, 2014.

[28]. R. H. Westgaard and A. Aarås, "Postural muscle strain as a causal factor in the development of musculo-skeletal illnesses," Applied Ergonomics, vol. 15, no. 3, pp. 162–174, 1984.

[29]. Jarnail Singh, C.M.Peng, M.K.Lim and C.N.Ong, "An anthropometric study of Singapore candidate aviators", Journal of Ergonomics, 38:4, 651-658, 2007.

[30]. Sanjiv Sharma , K.S. Raju and Anupam Agarwal, "Static anthropometry: Current practice to determine aircrew aircraft compatibility", Indian Journal of Aerospace Medicine, 51(2), 40-47, 2007.

[31]. Mehmet Burak Senol, "Anthropometric evaluation of cockpit designs", International Journal of Occupational Safety and Ergonomics, Volume 22- Issue 2, 246-256, 2016.

[32]. Robert E. Joslin, "Examination of Anthropometric Databases for Aircraft Design", Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting – 2014.

[33]. Kremser, F., Guenzkofer, F., Sedlmeier, C., Sabbah, O., Bengler, K., "Aircraft seating comfort: the influence of seat pitch on passengers'well-being". Work 41: 4936–4942, 2012.

[34]. Paul, G., Daniell, N., Fraysse, F., "Patterns of correlation between vehicle occupant seat pressure and anthropometry". Work 41: 2226–2231, 2012.

[35]. Reed, M.P., Manary, M.A., Flannagan, C.A.C. and Schneider, L.W., "Effects of Vehicle Interior Geometry and Anthropometric Variables on Automobile Driving Posture". Journal of the Human Factors and Ergonomics Society 42(4): 541–552, 2000.

[36]. Alan Hedge, Kimberly Rollings and Jennifer Robinson, "Green Ergonomics: Advocating for the Human Element in Buildings", Proceedings of the Human factors and Errgonomics Society 54^{th} annual meeting, 693-697, 2010.

[37]. Erminia Attaianese & Gabriella Duca, "Human factors and ergonomic principles in building design for life and work activities: an applied methodology", Theoretical Issues in Ergonomics Science, Volume 13- Issue 2, 187-202, 2012.

[38]. Erminia Attaianese, "A broader consideration of human factor to enhance sustainable building design", Work-41, 2155-2159, 2012.

[39]. N. G. Miller, D. Pogue, Q. D. Gough and S. M. Davis, "Green Buildings and Productivity", Journal of Sustainable Real Estate, 1:1, 65-89, 2009.

[40]. Nidhi Dwivedy, "Challenges faced by the Agriculture Sector in Developing Countries with special reference to India", International Journal of Rural Studies, vol. 18-2, 2011.

[41]. Thapa, G. and R. Gaiha, "Smallholder farming in Asia and the Pacific: Challenges and Opportunities", paper presented at the Conference on new directions for small holder agriculture, Rome, IFAD, 2011.
[42]. Amitabha De and Rabindra Nath Sen., "Ergonomic Evaluation of ploughing process of paddy cultivation in India", J. Human Ergol., 15:103-112, 1986.
[43]. Onuoha S.N., Ajayi O. and Imanogor P.A, "Hand anthropometry of agricultural workers in Ebony state central zone of Nigeria", International Journal of Engineering Research and Technology, Vol-2, Issue 4, 500-508, 2013.
[44]. D.Ramesh and H.P. Girishkumar,"Agriculture Seed Sowing Equipments: A Review", International Journal of Science, Engineering and Technology Research, Volume 3, Issue 7, 1987-1992, 2014.
[45]. A. R. Kyada and D. B. Patel, "Design And Development Of Manually Operated Seed Planter Machine", 5th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014)2014, IIT Guwahati, Assam, India,Dec 2014.
[46]. Abhijit Khadatkar, R. R. Potdar, Harsha Wakudkar and Bhagwan Singh Narwariya "Women Friendly Tools and Equipment Used in Rice Cultivation", Popular Kheti Vol -2, Issue-3, 69-71, 2014.
[47]. UNWWDR (The United Nations World Water Development Report). "Water for People, Water for Life-Executive Summary", UNESCO Publishing: Paris, France, 17–18, 2003.
[48]. Pravin K. Bhuse and Ravindra T. Vyavahare "Ergonomic Evaluation of Knapsack Sprayer used in Agricultural Application", International Journal of Scientific & Engineering Research, Volume 5, Issue 12, 903-907, 2014.
[49]. Nag, P.K., Goswami, A., Ashtekar, S.P., and Pradhan, C.K., "Ergonomics in sickle operation". Applied Ergonomics, 19 (3), 233-239, 1988.
[50]. Faiz Syuaib M. "Ergonomic of the manual harvesting tasks of oil-palm plantation in Indonesia based on anthropometric, postures and work motions analyses", Agric Eng Int: CIGR Journal, Vol. 17, No. 3, 248-262, 2015.
[51]. Thomas R.E., "The Anthropometry of Forest Machine Operators in the Southern USA", Journal of Forest Engineer, 33-41, 1992.
[52]. Dewangana K.N., Owary C. and Datta R.K. "Anthropometric data of female farm workers from north eastern India and design of hand tools of the hilly region", International Journal of Industrial Ergonomics, Volume 38, Issue 1, January 2008, 90-100.
[53]. Mohanty S. K., Behera B. K. and Satapathy G. C. "Ergonomics of Farm Women in Manual Paddy Threshing", Agricultural Engineering International:CIGR E-journal. Vol. X. June, 2008
[54]. Bini Sam, "Ergonomic Evaluation of Paddy Harvester and Thresher with Farm Women", International Journal of Science and Research (IJSR), Volume 3 Issue 11, 1644-1648, 2014.
[55]. Khayer S.M., Patel T. and Dewangan K.N., "Ergonomic Design Improvement of Pedal Thresher: An Approach Combining Digital Human Modelling and Response Surface Analysis". J Ergonomics, 2017
[56]. Tewari V., Ailavadi R., Dewangan K. and Sharangi S. "Rationalized Database of Indian Agricultural Workers for Equipment Design". Agricultural Engineering International: the CIGR Vol. IX. August, 2007.
[57]. Kumar, P. and D. Chakrabarti, "User centered design input in mechanical engineering and design: ergonomics relevances". 6th International Ergonomics Conference on HWWE- 2009, 116-119.
[58]. Hsiao H., Whitestone B., Bradtmiller R., Zwiener J.,Lafferty C.,Kau T.Y. and Gross M., "Anthropometric criteria for the design of tractor cabs and protection frames", Ergonomics, Vol. 48, No. 4, 2005, 323-353.
[59]. More S.H. and Vyavahare R.T., "Anthropometric and grip strength data of agricultural workers for Marathwada region of Maharashtra (India)", International Journal of Applied Engineering and Technology, Vol.4 (2), 2014, 148-153.
[60]. Agrawal K. N., R. K. P Singh, and K. K. Satapathy., "Anthropometric considerations of farm tools/machinery design for tribal workers of northeastern India". Agric Eng Int: CIGR Journal, 12(1), 2010, 143-150.
[61]. Yadav Rajvir, Sahastrarashmi Pund, N. C. Patel and L. P. Gite., "Analytical study of strength parameters of Indian farm workers and its implication in equipment design" Agric Eng Int: CIGR Journal, Vol. 12, No.2, 2010, 49-54.

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