ANTHROPOMETRIC PARAMETERS OF TRACTOR OPERATORS IN KANO STATE,NIGERIA

Ahmad[1,2], H. I., Ahmad[2], D., Suleiman[3], M. L. and Aziz[2], S.
[1]Department of Agricultural Engineering, Faculty of Engineering, BayeroUniversity, Kano,Nigeria
[2]Department of Biological and Agricultural Engineering, Universiti Putra Malaysia
[3]Department of Agricultural Engineering, Ahmadu Bello University, Zaria, Nigeria

Email: habibu1963@yahoo.co.uk

ABSTRACT

An anthropometric survey was conducted in Kano State of Nigeria to provide major anthropometric parameters of tractor operators for easy adaptation to tractors available. Six easily determined body dimensions related to tractor control components (hand and leg levers) design were measured for a sample of 43tractor operators. Data were analyzed statistically and the mean, Coefficient of Variation and Standard Deviation calculated. The variation was found at 5% level of significance. Dimensional models are suggested for 5th and 95th percentile drivers, which may be used as design tools. Knowledge of user dimensions can aid proper machinery adaptation since no manufacturer can design for all potential users. This would reduce occupational injury and enhancing safety and productivity since the operator is the major participant when total productive maintenance (TPM) is being considered.

KEYWORDS: Operator, Tractor, anthropometry, hand-and foot-controls, adaptation, Kano State

1.0 INTRODUCTION

The increase in population in most countries has necessitated the use of tractors and other farm implements in food production and processing to feed the growing population.

Kano State has been leading other regions in Nigeria in terms of population for over three decades. This region is also blessed with abundant fertile land with favourable rainfall and large bodies of water for irrigation. This large population needs to be fed, clothed, sheltered and provided with other basic infrastructure for progressive modern development. The need for sufficient food for healthy growth in any society cannot be overemphasized. Traditional methods of farming using hand- and animal- drawn equipment over the years is giving way for tractor-powered machines to increase production, release more labour for the urban industries and make farming more attractive to the youth.

The farm tractor is one of the machines that form the pivot of agricultural mechanization and the basis for the utilization of other machines/equipment for various agricultural operations as ploughing, harrowing, ridging, planting, weeding, fertilizer application, harvesting and transportation within and outside the farmstead (Nkakini et al., 2008). The operator apart from operating the tractor can perform many maintenance activities such as housekeeping, equipment cleaning/sheltering, lubrication, inspection and routine adjustments (Stephens, 2004). However, these could only be possible if the operator is not over stressed due to non-compatibility or adaptation with the tractor design.

In order to meet the challenges of increased mechanical power for agriculture, various tractor importations and establishment of tractor assembly plants were embarked upon in Nigeria since late 1970's, as farm mechanization has been proposed as the only way out for all the issues plaguing agricultural operations (Powar and Aware, 2007). This resulted in myriad of tractor makes and models in most organizations in charge of mechanization programmes. Unfortunately, this effort at mechanization did not yield the expected results due to the fact that many of the tractors were imported without spare parts or not suitable for the Nigerian farming population (Yisa, 2002).

Yisa (2002) assessed the ergonomic suitability of two makes of assembled tractors (Fiat and Steyr) designed and manufactured in Europe using 20 randomly selected subjects. Eleven anthropometric parameters were measured (Table 1).

Table 1: Anthropometric data of subjects

	mean	**Standard deviation**	**5th percentile**	**95th percentile**
Standing height, cm	169.3	10.7	151.7	186.9
Full-hand length, cm	79.5	5.1	71.1	87.9
Popliteal length, cm	51.3	4.0	44.8	57.8
Body weight, kg	56.0	4.6	48.4	63.6
Seat-pan width, cm	31.0	1.8	28.0	34.0
Seat-pan depth, cm	54.2	5.3	45.5	62.9
Seat-back support height, cm	31.2	1.7	28.3	34.0
Elbow height, ccm	49.5	5.0	41.3	57.5
Hand-pan width, cm	10.2	1.3	8.1	12.3
Hand grip, cm	9.7	1.2	7.8	11.6
Full-leg length, cm	90.6	10.7	79.95	108.1

Source: Yisa, (2002)

Results show that with the provision of footsteps in the Fiat 80-66, the task of getting onto the tractor is made easier than in the case of Steyr 8075 where this facility is not available. Although the seat design was adjudged to be satisfactory in both tractors, lack of adjustable back support does not give good protection to the operators' spinal column. The steering wheel is very easily operated in the Fiat 80-66 which is not the case with Steyr 8075. Hand and foot controls are located at convenient locations.

Mokdad, (2002) did a study on anthropometry of Algerian farmers where 514 male farmers were selected and data on 36 body dimensions taken. These body dimensions were thought to be useful for the design and redesign of agricultural equipment and tools. Out of these only 18 are found relevant for tractor operators.

Different statistical methods can be used in anthropometric studies. The choice of method depends to a great extent upon the nature of data and the purpose for which they are collected and presented. Mokdad, (2002) uses descriptive and inferential statistics to make data suitable for design purposes and to study the differences which might exist between the subject groups.

Victor et al., (2002) conducted an anthropometric survey of Indian farm workers to approach ergonomics in agricultural machinery design (Table 2). Anthropometric data varies from one region to another worldwide. Majumdar (1972) reported that body dimensions of Indians vary from region to region. Anthropometric surveys of western, northern, central and southern India have been reported (Fernandez and Uppugonduri, 1992).

Table 2: Comparison of anthropometric data of Indian (Chhattisgarh region) male farm workers with Western data

S/No.	Body dimension	Indian	American NASA (1978)	Swedes NASA (1978)	Germans (Jurgens et al., 1972)	Japanese, (Yokohori, 1972)
No. of subjects		300	3091	87	NA	NA
1	Weight (kg)	56.69	74.9	71.6	NA	NA
2	Stature	163.78	173.2	174.1	174.5	165.8
3	Chest circumference (cm)	82.79	99.2	NA	NA	NA
4	Bideltoid breadth	36.40	NA	NA	NA	NA
5	Arm length	82.4	NA	NA	NA	NA
6	Sitting height	77.47	90.5	NA	91.9	NA
7	Popliteal height (sitting)	49.84	44.0	NA	45.4	NA
8	Buttock popliteal length	57.64	49.4	NA	NA	NA
9	Hip breadth (standing)	30.60	35.4	NA	NA	NA

Source: Victor et al., (2002). Note: Unit, cm unless otherwise stated; NA , not available.

Nine measurements selected from a farm machinery design point of view were taken. These include body weight, stature, chest circumference, bideltoid breadth, arm length, sitting height, popliteal height (sitting), buttock popliteal length and hip breadth (standing). They found a maximum coefficient of variation (12.42%) in body weight and minimum in stature (3.39%). Static body dimensions differ from dynamic ones which are used for design and redesign of equipment, tools and work places. Dynamic measurements are more representative of human activities. To translate static body measurements into dynamic ones, Kroemer's suggestions (Kroemer, 1983) can be followed.

Patel et al., (2000) developed an ergonomic facility for improvement of tractor designs. They generated anthropometric data for Indian population and used it for the development of work space envelopes.

Tractors are companions for many agriculture workers. Well-designed human–tractor interfaces, such as well-accommodated tractor operator enclosures (i.e. cabs, hand-and foot controls and protection frames) can enhance worker productivity, comfort and safety (Matthews 1977, Kaminaka 1985, Liljedahlet al. 1996).

More recent design parameters – impediment of steering wheel, hand controls and protection frames for tractor drivers – were not specifically examined at that time. Over the following five decades, two concepts–the need to establish operator space envelopes and tractor control locations that fit operators' body size – have been increasingly recognized as important design elements (Dupuis 1959, Adams et. al. 1975, Purcell 1980, Bottoms 1983, SAE International 1989, 1992, 1994, Yadav and Tewari 1998). At the current time, these design parameters are considered standards. Adjustable seats, steering wheels and other controls have become the norm.

One of the important principles of ergonomics is that workplace dimensions should match the body dimensions of the expected users (Mokdad, 2002). A good match can be obtained if anthropometric data are applied. Incorrect workplace design where anthropometric data are ignored can cause psychological discomfort, physical fatigue and could be harmful and damaging in the long term. Thus, anthropometric data are essential for the design of safe, comfortable and effective machines, tools and workplaces. In the developed countries, structured and highly developed researchers have been collecting anthropometric data from different segments of the populations for a long time. The first systematic large-scale anthropometric studies were started in the 1940s (Mokdad, 2002). In developing countries, many researchers have collected anthropometric data for the purpose of designing tools, equipment, workplaces and assessment of compatibility of existing facilities with intended users.

Hsiao et al. (2005) determined the critical anthropometric measures and 3- D feature envelopes of body landmarks for the design of tractor operator enclosures. One hundred agriculture workers participated in the study. Their body size and shape information was registered, using a 3-D full-body laser scanner. Knee height (sitting) and another eight parameters were found to affect the cab-enclosure accommodation rating and multiple anthropometric dimensions interactively affected the steering wheel and gear-handle impediment. A principal component analysis has identified 15 representative human body models for digitally assessing tractor-cab accommodation. A set of centroid coordinates of 34 body landmarks and the 95% confidence semiaxis- length for each landmark location were developed to guide tractor designers in their placement of tractor control components in order to best accommodate the user population.

Finally, the vertical clearance (90 cm) for agriculture tractor enclosure in the current SAE International J2194 standard appeared to be too short as compared to the 99th percentile sitting height of male farm workers in this study (100.6 cm) and in the 1994 National Health and Nutrition Examination Survey III database (99.9 cm) and of the male civilian population in the 2002 Civilian American and European Surface Anthropometric Resource database (100.4 cm).

The tractor industry and the agricultural community have a pressing need for a scientifically rigorous assessment of the fit, adaptation and function of these products. The operator could work longer hours with a tractor suiting his hand/leg reaches (Sanders and McCormick, 1993) and comfortable seat and back rest. This paper describes the development of an anthropometric model of tractor operators from Kano State of Nigeria for adaptation to tractor makes available by managers of tractor fleets.

2.0 MATERIALS AND METHODS

2.1 Study Area and Selection of Tractor Operators

Kano State (Fig. 1) has forty four Local Government Areas (LGAs) and ten LGAs (Ajingi, Albasu, Bebeji, Bichi, Bunkure, Dawakin Kudu, Gwarzo, Kabo, Makoda and Tudun Wada) were selected for this study. These are spread across the length and breadth of the state. In each LGA visited, the anthropometric measurements of available tractor operators working in the organization were documented using a structured questionnaire.

2.2 Main Study Concept

This study was conducted as part of a larger work on assessment of tractor downtime in an organization as composed in a flowchart (Figure 2). This article concerns the first part on operator anthropometry adaptation to tractor ergonomics design. The second (on repair and maintenance (R&M)) costs prediction models) and the third (on engine condition assessment using atomic spectrometry oil analysis) parts have been treated (Ahmad, et al. 2012, 2014a and 2014b).

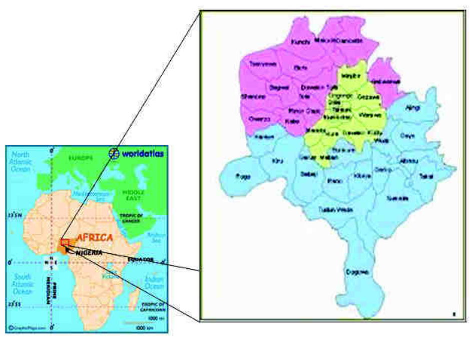


Figure 1: Map of Kano State of Nigeria

2.3 Determination of Operator Anthropometric Data

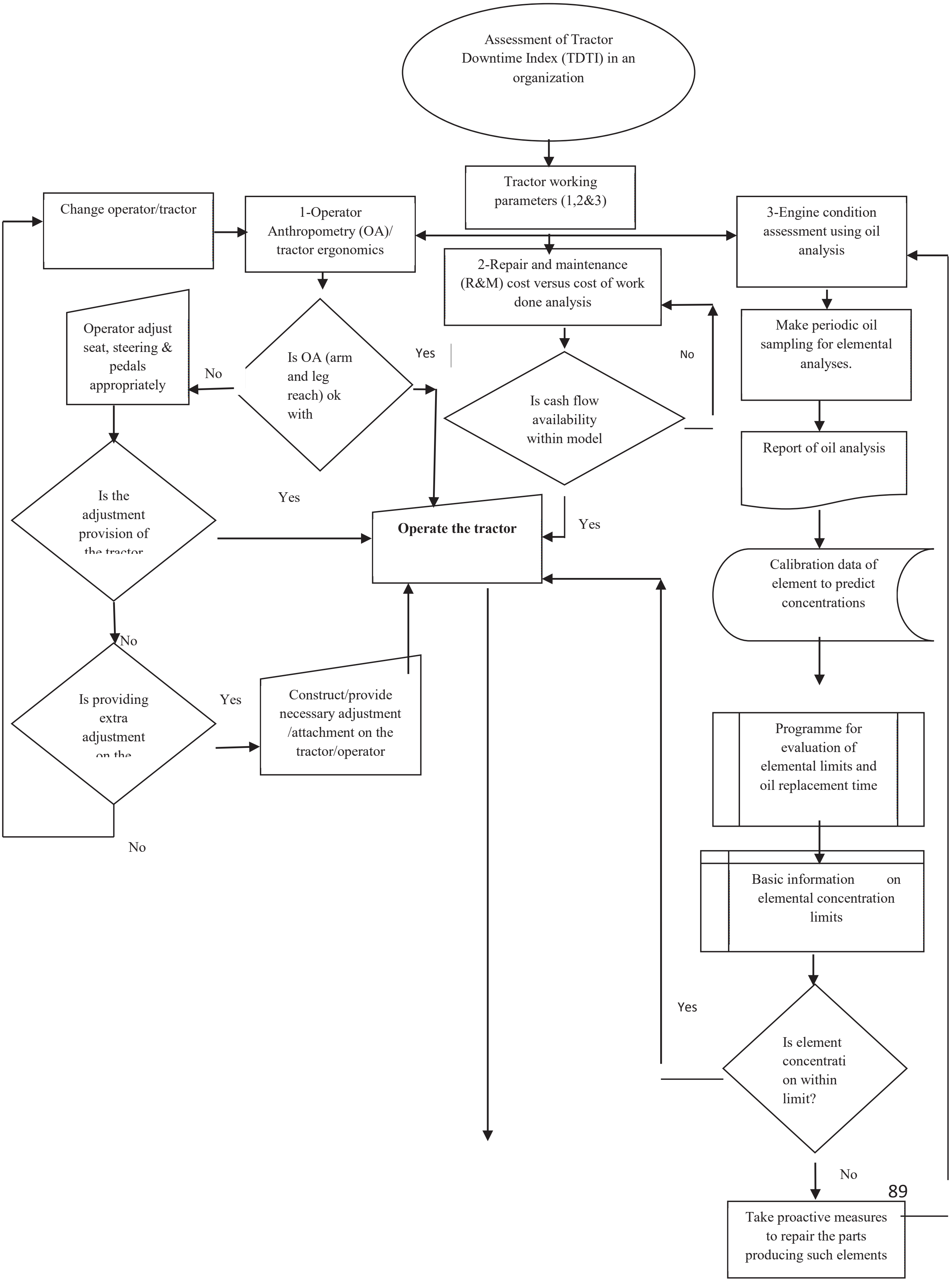
The data were taken carefully to measure six fundamental body measurements (body weight, standing height/stature, full hand length, elbow-fingertip length, full leg length and knee length) for the tractor operators in correct posture and precise manner. Standing height (stature) and body weight were measured in standing posture. Subjects were asked to stand on a flat surface and very close to an erect wall exceeding their height. Correct standing posture was ensured with their feet closed and their body vertically erected, while their heels, buttocks and shoulders touching the same vertical wall. A straight edge ruler was placed horizontally on top of the subject's head and touching the wall. The position of the ruler against the wall is marked with white chalk and the reading from the floor to the mark taken using graduated tape.

A standard bath room weighing balance was used in taking the body weight by placing it on a flat surface and asking the subjects to climb it after removing any apparel (cap, shoes, wrist watch, GSM handset, etc).

The other four measurements were taken in a sitting position by asking the subjects to sit on an adjustable chair without back rest. After sitting on the chair at a level corresponding to the knee height (by making 90^{o} angle between shin and thigh) and pushing the chair until the buttock, shoulder and head were touching the vertical wall.

2.4 Anthropometric Data Analysis

The tractor operator's anthropometric data collected were analysed to produce anthropometric model parameters of the study area. The parameters were evaluated as was done by Yadav et al. (1999) in deriving the anthropometric model of Indian tractor operators. These include: mean, standard deviation, coefficient of variation, range and percentiles (5^{th}, 95^{th} and difference between the two).


Assessment of Tractor Downtime Index (TDTI) in an organization
Tractor working parameters (1,2&3)
Change operator/tractor
1-Operator Anthropometry (OA)/ tractor ergonomics
3-Engine condition assessment using oil analysis
2-Repair and maintenance (R&M) cost versus cost of work done analysis
Operator adjust seat, steering & pedals appropriately
No
Is OA (arm and leg reach) ok with
Yes
No
Is cash flow availability within model
Make periodic oil sampling for elemental analyses.
Report of oil analysis
Is the adjustment provision of the tractor
Yes
Operate the tractor
Yes
Calibration data of element to predict concentrations
No
Is providing extra adjustment on the
Yes
Construct/provide necessary adjustment /attachment on the tractor/operator
Programme for evaluation of elemental limits and oil replacement time
No
Basic information on elemental concentration limits
Yes
Is element concentrati on within limit?
No
Take proactive measures to repair the parts producing such elements

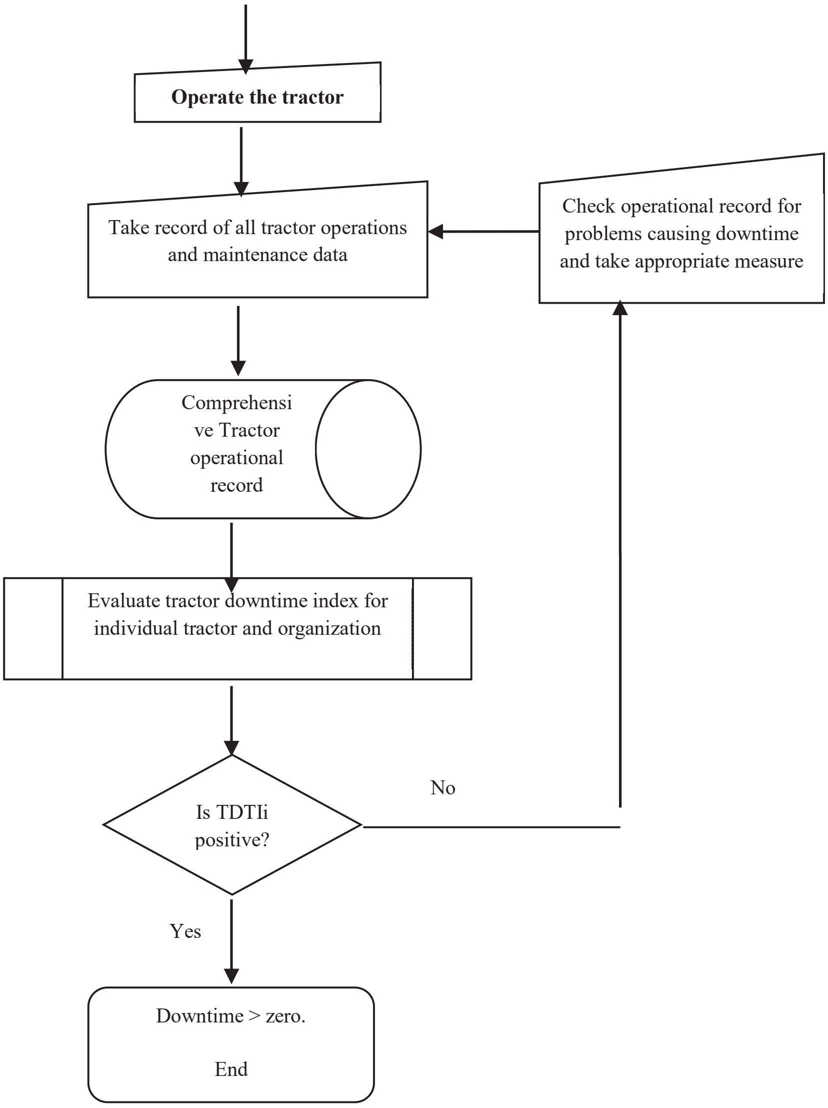


Fig. 2: A flowchart showing an application of anthropometric parameters

3.0 RESULT AND DISCUSSIONS

A total of forty three tractor operators were captured in the ten LGAs surveyed. The analysed data obtained are presented in Table 3. The anthropometric data of tractor operators (Table 3) could be used to adapt individual operator to the particular tractor model to work with. Since operators of tractors can be changed from time to time, manufacturers cannot provide design/adjustments for all likely subjects in a particular market segment. Therefore, tractor fleet managers could easily use these six measurements and make appropriate modifications (as shown in the study flowchart –section 1 of Fig. 2) to match operators with tractors available especially concerning hand controls which has the highest coefficient of variation (19%) in the study area (Table 3). Studies by Jain et al. (2008) showed that present tractor seats in India need minor modifications/improvements in seating dimensions as per BIS recommendations. This may cause excessive pressure on the underside of the thigh, which can reduce blood circulation to the lower legs.

Dimensional models are suggested for 5th and 95th percentile drivers, which may be used as design tools. Knowledge of user dimensions can aid proper machinery design for reducing occupational injury and enhancing safety and productivity as suggested by Yadav et al. (1999) in their study of anthropometric model of tractor operators in India.

Table 3: Anthropometric data of tractor operators from the study area (n= 43).

Body dimension	**Mean**	**CV**	**SD**	**Range**	**Percentile**		
					5th	**95th**	**Diff btw 95th and 5th**
Body weight (kg)	65.1	0.05	7.7	47-96	54	180	
Stature (cm)	167.5	0.07	5.4	152-183	156	180	24
Full-hand length (cm)	74.13	0.19	12.7	64-87	68	83	15
Elbow to fingertip length (cm)	47.23	0.06	2.8	42-53	43	51	8
Full-leg length (cm)	104.37	0.07	7.0	94-122	98	116	18
Knee length (cm)	52.24	0.06	3.4	47-61	49	58	9

Short operators will require lower steps for access on the tractor. Statistical analysis has revealed that 42 % of tractor accidents in a study were encountered during climbing in and out of the cab (Suutarinen, 1992). Light weight operators could be ballasted with additional weight to damp vibrations from engine and surface terrain in order to obtain maximum allowable driving time per day (Maleki, et al., 2008). Leg and arm controls should be adaptable to subjects reach (Table 3), if designed adjustment limits are not adequate. These figures are not for generalization but for use to adapt existing ergonomic designs of tractors to suit available subjects which could reduce tractor accident by more than 20% (Suutarinen, 1992). Meister (1971) in his famous four principles of human factors design philosophy stated that it is easier to modify/adapt equipment characteristics than to modify human capabilities. That is, it is easier to design controls to be actuated within 'human' force capabilities and to locate them within 'human' limits of reach than to endure the operator with greater strength or to change his physical dimensions to a more desirable configuration. Tractors require more pedal force than road vehicles (Mehta, et al., 2007). They also stated that clutch and brake pedals on Indian tractors be optimally positioned based on stature dimension at 40% in front and 19% below the seat reference point (SRP)

Staff turnover is inevitable in any organization. This may be caused by retirement, promotion, resignation, termination or even death. Replaced staff may be trained to any level but the anthropometric dimensions for compatibility with the machine operated by the former staff cannot be met always. Therefore, qualified agricultural engineers are required as managers of tractor fleets. This would enable them make necessary adjustments to existing tractor ergonomic designs to suit available manpower recruited as tractor operators.

One of the main reasons for piston scuffing or scoring is overloading an engine due to driving habits and harsh operating conditions (Singh, 2005). If the operator is not well suited with the tractor, his behavior will be erratic and non-consistent.

4.0 CONCLUSION

This study conducted a survey on tractor operators in Kano state of Nigeria and determined their anthropometric models for adaptation with the available tractor ergonomic designs. The highest coefficient of variation (19%) among the six parameters measured was in the full-hand length. This calls for better strategies of adapting tractor hand controls to the user population by the tractor fleet managers.

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