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Review of anthropometric considerations for tractor seat design

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Abstract

Tractor driving imposes a lot of physical and mental stress upon the operator. If the operator's seat is not comfortable, his work performance may be poor and there is also a possibility of accidents. The optimal design of tractor seat may be achieved by integrating anthropometric data with other technical features of the design. This paper reviews the existing information on the tractor seat design that considers anthropometry and biomechanical factors and gives an approach for seat design based on anthropometric data. The anthropometric dimensions, i.e. popliteal height sitting (5th percentile), hip breadth sitting (95th percentile), buttock popliteal length (5th percentile), interscye breadth (5th and 95th percentile) and sitting acromion height (5th percentile) of agricultural workers need to be taken into consideration for design of seat height, seat pan width, seat pan length, seat backrest width and seat backrest height, respectively, of a tractor. The seat dimensions recommended for tractor operator's comfort based on anthropometric data of 5434 Indian male agricultural workers were as follows: seat height of 380 mm, seat pan width of 420–450 mm, seat backrest width of 380–400 mm (bottom) and 270–290 mm (top), seat pan length of 370 $\pm$ 10 mm, seat pan tilt of 5–7° backward and seat backrest height of 350 mm.

Relevance to industry

The approach presented in this paper for tractor seat design based on anthropometric considerations will help the tractor seat designers to develop and introduce seats suiting to the requirements of the user population. This will not only enhance the comfort of the tractor operators but may also help to reduce the occupational health problems of tractor operators.

Keywords: Tractor; Seat; Anthropometric data; Seat design

1. Introduction

The nature of tasks on a tractor necessitates a number of actions to be performed by the operator, which puts varying physiological demands on the body. Examples of these tasks are steering of tractor, looking backward to observe and control the machine/implement, and operating clutch, brake, and hydraulic control levers. The task and workplace determine the postures and create a pattern of loading on the structures of the body of the individual. The seat is one component affecting these loads. Tractor seat design can be used as a means to modify loads on the body structures to reduce operator's discomfort (Mehta and Tewari, 2000).

The agricultural tractor driving requires the operators to maintain a stable posture despite dynamic conditions. These requirements may involve a large number of turning movements from looking ahead to behind and vice versa resulting into a poor posture (Donati et al., 1984). The seating comfort is strongly related to postural support characteristics of the seat. It is desirable to design seats that can provide a comfortable and controlled seating posture (Grandjean, 1988).

Dupuis (1959) investigated the strain on the tractor operators during operation of different controls. It was observed that human energy consumption could be reduced by 13–29% by making improvement in tractor controls and seat. It was concluded that the efficiency and comfort of the operator were improved with a properly designed tractor workplace.

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Whyte and Stayner (1984, 1985) conducted subjective trials on various aspects of tractor seat design, which contributed to the postural support of the driver. Ten subjects tested five combinations of backrest and seat pan, such that each subject used each backrest and each seat pan once, the seat pans and backrests were changed after every 15 min run. They obtained optimum values of tractor seat pan width, seat length, backrest width, backrest height and backrest inclination and are reported in Table 1. Tewari and Prasad (2000) concluded that the seat pan with radius of curvature 750 mm, backrest with radius of curvature 300 mm and backrest inclination of 10° were the most suitable values for Indian tractor operators.

Shao and Zhou (1990) described the design principles of tractor driver-seat static comfort from ergonomics viewpoint. They considered geometric parameters of seat construction from anthropometric data of Chinese population. The included geometric parameters were lumbar support, backrest slope angle, seat width, seat length, seat height, seat pan angle, etc. They concluded that the seat position should be vertically and longitudinally adjustable. Seat should allow the operator to change his position from time to time in order to relieve pressures and rotate muscle groups under tension. The position of lumbar support should be vertically adjustable.

The International Standard (ISO 4253, 1993) and Indian Standard (IS 12343, 1998) lay down range of dimensions for the operator's seat and location of specific control relative to the seat index point (SIP) within the seating accommodation on agricultural tractor with a track width greater than 1150 mm (Fig. 1) and are given in Table 1. The SIP as per ISO 5353 (1984) is the interaction on the central vertical plane passing through the seat centre-line of the theoretical pivot axis between a human torso and thighs. At present, the Bureau of Indian Standard (IS 12343, 1998) has incorporated most of the requirements of the ISO 4253 (1993) standard except seat height. The ISO standard is primarily based on the data of Western/European workers.

Mehta (2006) evaluated five designs of tractor seats provided on most popular brands of 35–45 hp Indian tractors. The measured dimensions like seat length, seat width, seat backrest width and seat backrest height ranged 335–366, 417–470, 373–415 and 260–300 mm, respectively, on the tractor seats. The results indicated that there was a wide variation in seat dimensions on different models of tractors seats provided by different manufacturers. However, the different models of the tractors are being used by the same anthropometric population of Indian tractor drivers. It was concluded that there was a need to consider anthropometric data of user population in the tractor seat design to improve comfort and safety of tractor drivers.

The recommendations on tractor seating dimensions given by various researchers (Donati et al., 1984; Shao and Zhou, 1990; Whyte and Stayner, 1984, 1985) are reported in Table 1 and these are compared with IS 12343 (1998) and ISO 4253 (1993) standards. Table 1 shows that there is a variation in recommendations for seating dimensions by various investigators. This may be due to variation in anthropometric dimensions of the user population. However, the recommendations meet the ISO 4253 (1993) standard except for seat length and seat backrest inclination. This is due to large range of dimensions in the ISO 4253 (1993) and IS 12343 (1998) standards.

Seat design provides the interface between a mechanical system, the tractor, and the delicate and sensitive biological system, the human operator. Modern tractor seat design is an interdisciplinary task relying upon the latest advances in seating dynamics, ergonomics and human factors, and structural mechanics. The design parameters for tractor seat must simultaneously meet three design objectives, namely, comfort, health and safety of the operator. The comfort refers to the ergonomic and human factor considerations such as seat dimensions and their adjustments, cushioning materials, and operator perception of comfort. The health refers to the long-term spinal support, seat ergonomics and terrain-induced vibration attenuation.

Table 1
Comparison of recommendations on tractor seating by various researchers with ISO standard

Dimensions	ISO 4253 (1993)	IS 12343 (1998)	Shao and Zhou (1990)	Whyte and Stayner (1984, 1985)	Donati et al. (1984)
Seat pan width[a] (mm)	>450	⩾450	⩾400	450–480, 465 (optimum)	⩾450
Seat length[b] (mm) (in front of SIP)	210–310	210–310	240–290	300–330	250–310
Seat pan tilt[c] (°)	3–12	3–12	3–7	–	4.5–10
Seat backrest width (mm)	–	–	–	350–425	–
Seat backrest height (mm) (above SIP)	>260	>260	–	300–330	333
Seat backrest inclination (°)	95–105	95–105	105–115	102–103	>111
Seat height[d] (mm)	–	<540	380–400	–	–

[a]The horizontal distance between the outside edges of the seat surface measured in a plane perpendicular to the median plane of the seat or the width measured along a horizontal transverse line passing through the seat index point (SIP).

[b]The horizontal distance parallel to the longitudinal plane of the tractor measured from the front edge of the seat cushion (offset 150 mm on either side of the longitudinal centreline) to the 140 mm to the rear of the vertical transverse plane containing seat index point (SIP).

[c]It refers to the angle of the seat pan to the horizontal.

[d]It is measured from footrest to front of seat surface with 55 kg weight on the tractor seat.

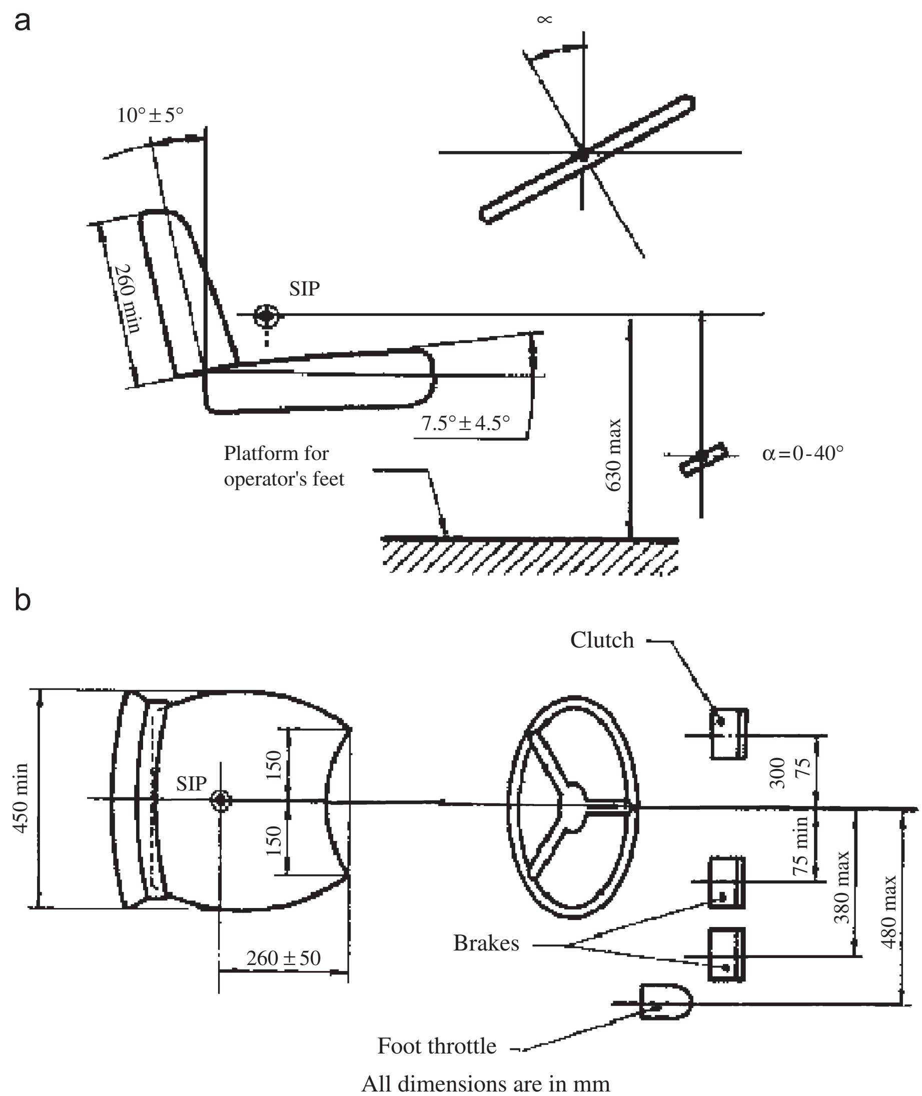

Fig. 1. Operator's seating accommodation (IS 12343, 1998). SIP is normally 90 mm above and 140 mm in front of seat reference point (SRP): (a) side view and (b) plan view.

The safety refers to the ability of the seat to keep an operator "in position" during an accident.

A tractor seat design must take into account human/biomechanics perspectives which are energy and vibration absorbing and which do not disrupt the spinal configuration and the spinal geometry. The biomechanical and engineering factors such as ride vibration, pressure distribution at the seat–operator interface and the body posture play an important role in the tractor seat design. With a constant need to improve tractor operator comfort and safety under dynamic condition, progress has been made in attenuating ride vibration levels (Bovenzi and Betta, 1994; Fairley, 1995; Matthews, 1964; Mehta et al., 2000; Rakheja and Sankar, 1984; Suggs, 1998; Tewari and Prasad, 1999; Wang et al., 2006). A well-designed tractor seat should be able to accommodate conveniently operators of various sizes (5th–95th percentile) and shapes. It should provide adequate body support and geometric parameters of seat with respect to anthropometric data of users. This paper deals with review of anthropometric considerations for tractor seat design.

2. Theoretical considerations

The design of a tractor seat should give due consideration to static and dynamic performance requirements.

2.1. Functions of tractor seats

The requirements for a comfortable tractor seat (Purcell, 1980; Stikeleather, 1981) are as follows:

(1) The seat should provide a comfortable and controlled seating posture.
(2) It should reduce mechanical shock and vibration transmitted to the operator.
(3) It should position the operator to provide easy and non-fatiguing access to machine controls.

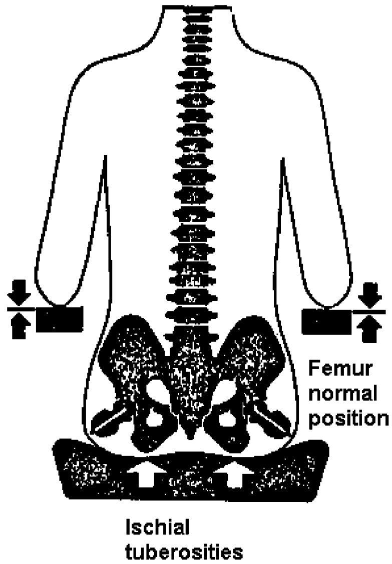

Fig. 2. Horizontal seat with the femur bones in a normal (unstressed) position (Purcell, 1980).

(4) It should position the operator relative to the tractor to provide adequate vision for allowing him to perform all works safely and effectively.
(5) The seat should support the weight of the thighs and upper body. The ischial tuberosities must be capable of supporting most of the upper body weight (Fig. 2).
(6) A good-seated posture should support the spine to approximate the correct curvature. The backrest should not be soft and over padded to prevent back ailments.
(7) The seat cushion underneath knee muscles should be soft and rounded off to change his position from time to time to relieve pressure and rotate muscle groups under tension.
(8) The tractor seat must support the body during many continuous hours of operation, especially to the lower back and thighs. This requires adjustability in the seat to accommodate all people in the percentile range that has been chosen.

2.2. Aspects of seated posture

The five primary aspects of maintaining a seated posture are orthopaedic, muscular, behavioural, biomechanical and anthropometric.

2.2.1. Orthopaedic

It relates to a possible damage to operator's health caused by poor seat design. The primary support structures of the body in a seated posture are spine, pelvis, legs and feet. The spine is a complex structure that serves to support the body, allows for bending and twisting of the trunk, protects and houses the spinal column, and also absorbs vertical shock to the body. The spinal column consists of 33 vertebrae, held together by tough bands of tissue called ligaments. The vertebrae are divided into five sections. There are seven cervical vertebrae (C-1 to C-7), 12 thoracic vertebrae (T-1 to T-12), five lumbar vertebrae (L-1 to L-5), five vertebrae attached to sacrum and four vertebrae attached to coccygeal (tailbone). The orientation of the lumbar and sacral vertebrae is important for seat design. This is because these vertebrae and their respective discs and muscles support most of the spinal load of a seated person.

The normal, relaxed spine appears vertical, when viewed from the front or back and curved, when viewed from the side. The top, cervical curve bends forward leading into a convex backward bend throughout the thoracic region. The lumbar region bends forward again, ending in the sacrum, which is positioned on the pelvis. This normal lumbar curve produces the optimum pressure distribution over the cervical discs, and the optimum level of static load on the intervertebral muscles (Oborne, 1986).

The comfortably seated position should ensure that the lumbar curve is in a normal position. The back muscles should be relaxed, no pressure should be exerted on the blood vessels from the upper body to the thigh, and the blood should circulate normally (Shao and Zhou, 1990).

2.2.2. Muscular

There are five major muscle groups which act directly to support and stabilise the spine. In addition to supporting the upper body, these muscle groups are responsible for providing the power to flex, extend, twist, and laterally bend the upper body. The vertebrae are kept in position by muscles and tendons, any alteration to a natural spinal shape will produce correspondingly stresses on the spinal musculature. Oborne (1986) suggested that an upright and a forward leaning posture would cause fatigue. The provision of seat backrest reduced lumbar fatigue and helped to stabilise the pelvis rotation.

2.2.3. Behavioural

Sitting behaviour can be characterised by regular movements or fidgeting, which helps relieve pressure maldistributions on parts of the spine. The degree of fidgeting could act as an indicator of seating discomfort. Muscular fatigue and spinal deformation may reduce performance. Yes, it is essential to design equipment which fit the users but it is also important to fit their cognitive capacities.

If the seat cushion is soft, it gives little support to the flabby muscle or fatty tissue; if it is compressed to the point of being solid (i.e. bottoming), the cushion is no different from a hard seat.

All of these observations lead to the antagonistic requirements that, on the one hand, the sitter needs to vary his posture to relieve pressure maldistribution; on the other hand, he needs to maintain, and actively seek stability (Oborne, 1986). An efficient and comfortable tractor seat, therefore, needs to be able to accommodate these homoeostatic requirements and allow the sitter both stability and flexibility.

2.2.4. Biomechanical

Biomechanics is defined as a combination of medical and engineering technologies to measure the interaction between people and products by calculating forces on and within the body. The forces exerted by arms or legs of a tractor operator must be transmitted through the body and the seat to the ground. The backrest is a channel for such forces on many occasions, otherwise the musculature of the trunk must be tensed to provide a semi-rigid path for the force transmission. The generated muscle tension will increase the load on the spinal column, particularly in the lumbar spine, which is the major channel for load transmission from the upper to the lower part of the body (Corlett, 1989). A backrest can also reduce loads on the lumbar spine by transmitting part of the gravity forces due to the head, arms and upper trunk (Corlett and Eklund, 1984). The comfort of a seat depends, in a dynamic sense, on the extent to which it permits muscular relaxation while stabilising the open-chain system of body links.

2.2.5. Anthropometric

The comfort of operator in a tractor seat is greatly affected by the extent to which the seat fits to the operator. Anthropometric measures vary considerably with factors such as size, gender, body type, race, age and country of origin playing a dominant role in this variability. The application of anthropometric data is, therefore, controlled largely by the anticipated user population. The anthropometric data bank assembled and maintained by the Aerospace Medical Research Laboratories, Dayton, OH, USA, is a large repository of raw anthropometric data in the world. In India, Anthropological Survey of India (ASI) has been involved in anthropometric data collection since 1945. The main aim of these surveys has been to collect data on morphological characteristics of various population groups for anthropological studies. A project on All India Anthropometric Survey was initiated by ASI in 1961 and continued till 1969. During this period, data on 60,000 male subjects from about 300 different castes/tribes/communities throughout the country were collected. The body dimensions included in this survey were stature, sitting height, weight and a few other dimensions. Some anthropometric data are available at Defence Institute of Physiology and Allied Sciences, Delhi. However, these data are on armed forces people. The National Institute of Design, Ahmedabad, published a monogram on anthropometric data of Indians. They have given data on 1000 subjects all over the country. However, most of the subjects here are from student community or other occupational groups. Gite and Yadav (1989) conducted an anthropometric survey on 39 farm workers from Central India. They illustrated the use of the data in the design of farm equipment through four examples.

The number of anthropometric surveys (Sen, 1964; Sen et al., 1977; Gupta et al., 1983; Yadav et al., 1997; Dewangan et al., 2005) carried out in the country are very small and are based on small sample size and the dimensions included were specific to the requirements. These case studies pointed out that there was a considerable difference between the anthropometric data of Indian and Westners. Therefore, it was felt necessary to conduct extensive surveys in different regions of the country to generate the necessary data useful in farm machinery design (Gite and Yadav, 1989).

3. Materials and methods

3.1. Anthropometric data of Indian agricultural workers

A detailed action plan was worked out for collection of anthropometric data on agricultural workers of India by the All India Coordinated Research Project (AICRP) on Ergonomics and Safety in Agriculture (ESA) located at the Central Institute of Agricultural Engineering (CIAE), Bhopal (Gite and Chatterjee, 1999). It included identification of body dimensions useful in farm equipment design, finalisation of methodology for data collection through cooperating centres of AICRP on ESA and Adhoc research schemes of State Agricultural Universities and compilation of data at CIAE, Bhopal. Keeping into consideration the design requirements of hand tools, animal drawn equipment, tractors, power tillers, power operated machines,

Fig. 3. Measurement of popliteal height sitting using Harpenden anthropometer.

self-propelled machines and workplaces, a total of 75 body dimensions and four skin folds parameters were identified for inclusion in the survey. The terminologies for anthropometric dimensions are according to NASA Anthropometric Source Book (NASA, 1978).

Anthropometric equipment (Fig. 3) having an accuracy of ±3 mm were used for measurement of body dimensions. Adequate training was given to field investigators for collection of anthropometric data. The anthropometric data of 5434 Indian male agricultural workers were collected by cooperating centres (Anonymous, 2005a, b, c, d) and adhoc research schemes centres (Anonymous, 2002, 2005e–h; Tewari, 2003) located in State Agricultural Universities/ Research Organisations located all over the country. The anthropometric data were analysed to calculate the mean, standard deviation (S.D.), and 5th (mean−1.645 × S.D.) and 95th (mean + 1.645 × S.D.) percentile values and the values for selected dimensions are reported in Table 2.

Table 2
Anthropometric data of Indian male tractor operators ($N = 5434$)

S. no.	Body dimensions[a]	Mean	SD	5th percentile	95th percentile
1	Age (years)	33	10	16	50
2	Weight (kg)	54.5	8.7	40.1	68.8
3	Stature	1633	67	1523	1743
4	Sitting height	820	73	700	940
5	Popliteal height sitting	414	29	366	463
6	Buttock popliteal length	440	37	379	500
7	Hip breadth sitting	309	32	256	362
8	Interscye breadth	305	32	253	357
9	Sitting acromion height	559	68	448	670

Values are in mm otherwise stated.
[a]The terminologies are according to NASA Anthropometric Source Book (1978).

3.2. Tractor seat design

Different body dimensions are the initial data used to determine the geometric parameters of a seat. The collected anthropometric data of Indian male operators were used for design of tractor seats based on anthropometric considerations. The seat characteristics that affect the operator's posture and static comfort are seat pan size (length and width) and its curvature and tilt, backrest size (height and width) and its curvature and inclination. The seat cushion and covering materials greatly affect the feeling of the operator and his well being in the seat. The important anthropometric data (Fig. 4) of agricultural workers compiled for tractor seat design were popliteal height sitting, buttock popliteal length, hip breadth sitting, interscye breadth and sitting acromion height. The geometric parameters of the tractor seat for Indian operators were finalised based on compiled anthropometric data, review of literature and by following relevant IS 12343 (1998) and ISO 4253 (1993) standards.

4. Results and discussions

Table 2 shows that the mean age of the selected male subjects was 33 ± 10 years and ranged 15–67 years. The mean values of stature and weight of Indian agricultural workers were 1633 ± 67 mm and 54.5 ± 8.7 kg, respectively. The 5th and 95th percentile values of stature were 1523 and 1743 mm, respectively. The principles adopted in the design of tractor seat based on anthropometric data of Indian

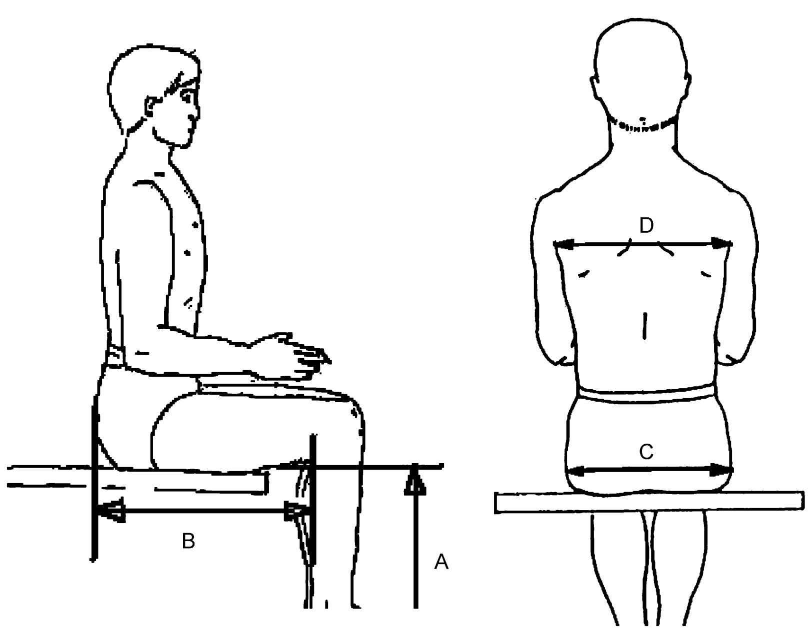

Fig. 4. Anthropometric dimensions for tractor seat design according to NASA Anthropometric Source Book (NASA, 1978): (A) Popliteal height sitting, (B) buttock popliteal length, (C) hip breadth sitting, (D) interscye breadth.

male agricultural workers are described in the following sections.

4.1. Seat height

The seat height should be low enough to avoid excessive pressure on the underside of the thigh. Such pressure may reduce blood circulation to the lower legs. The seat height should be lower than the distance from footrest to the underside of the thigh when the 5th percentile person is seated (i.e. popliteal height sitting) to reduce excessive pressure. The Bureau of Indian Standard (IS 12343, 1998) recommends that seat height should not exceed 540 mm. The 5th percentile value of popliteal height sitting of Indian agricultural workers was 366 mm. Therefore, the optimum seat height on Indian tractors should be 380 mm including the allowances for shoes. The seat height should be adjustable so as to generate a correct visibility at front and back for the driver to accomplish forward and backward tasks.

4.2. Seat pan width

In order to assure driver comfort and convenient posture change, the seat width should be wider than hip breadth sitting of 95th percentile operator. It should not be less than 400 mm (Grandjean et al., 1973; Shao and Zhou, 1990). The 95th percentile values of hip breadth sitting for agricultural workers of India and Punjab state of India were 362 and 396 mm, respectively. As per Bureau of Indian Standard (BIS), the seat pan width should not be less than 450 mm (IS 12343, 1998). However, based on anthropometric considerations this value should be 420–450 mm, including the allowances for operators' cloth.

4.3. Seat length

The seat pan length should be lower than 5th percentile value of buttock popliteal length keeping in view that there should be enough clearance between back of the lower leg and front edge of the seat for the 5th percentile operator. The seat length should not be too long so as to enable the driver to brace his legs to resist against vibration. The 5th percentile values of buttock popliteal length of Indian and West Bengal (East Indian state) male agricultural workers were 379 and 362 mm, respectively. Therefore, the seat length should not be more than 362 mm. The BIS recommends seat length of 400 ± 50 mm (IS 12343, 1998). Zander (1972) recommended seat length of 380 mm for Dutch people having mean stature of 1750 mm. Therefore, the seat length of 370 ± 10 mm was recommended for Indian tractor operators.

4.4. Seat backrest width

The function of a seat backrest is to maintain a relaxed (i.e. non-fatiguing) spinal posture. The shape and the inclination of the backrest are extremely important. The proposed dimensions of the backrest relate quite simply to the distance from the upper lumbar region to the underside of the buttocks and to the interscye breadth. The 5th and 95th percentile interscye breadth values of Indian agricultural workers were 253 and 357 mm, respectively. The trapezoidal shape seat backrest may be provided on tractor with smaller width on the upper part to have operators' free hand movement. Thus, the recommended seat backrest width at the bottom and top should be 380–400 and 270–290 mm, respectively, including the allowances for operators' cloth.

4.5. Seat backrest height

The backrest height is measured above the compressed seat, if padding is present. Many researchers suggested that backrest should have an open area of at least 125–200 mm to accommodate sacrum and fleshy parts of buttocks just above the seat pan and to allow the lumbar region to fit firmly into the backrest. A high backrest prevents full mobility of the arms and shoulder during rear viewing and operation of the hydraulic control levers in a tractor. The BIS recommends minimum seat backrest height of 260 mm (IS 12343, 1998). The 5th percentile value of sitting acromion height of Indian male agricultural workers was 448 mm. Thus, the height of backrest should be 348 mm (~350 mm), subtracting 100 mm from sitting acromion height to have free shoulder movement. The tractor seat backrest should support the lumbar region only and should be independently adjustable.

4.6. Seat backrest inclination

The inclination of the backrest to the seat pan serves two purposes. First, it prevents the operator from slipping forward, and second, it causes him to lean against the backrest with the lower (lumbar) part of his back and sacrum supported. In order that the trunk–thigh angle is in comfort range when sitting, this slope angle should be in the range of 95–105° from the horizontal (IS 12343, 1998). It is preferable to have an adjustable backrest inclination on tractor seat for better lumbar support.

4.7. Seat pan tilt

A seat pan that is tilted backwards will produce two effects. First, by the force of gravity the sitter's back is moved towards the backrest, thus supporting the back muscles. Second, a slight inclination of the seat pan at the front helps to prevent the gradual slippage out of operator from the seat. The Indian Standard (IS 12343, 1998) recommends a tilt of 3–12° backward for the seat pan. The optimum seat pan tilt of 5–7° backward was recommended for comfort and safety of tractor operators.

4.8. Seat pan concavity

The tractor seat pan should have a radius of curvature of 750 mm for Indian operators for better contact and more uniform pressure distribution at seat–operator interface (Tewari and Prasad, 2000).

4.9. Seat backrest concavity

The tractor seat backrests with a radius of curvature of 300 mm was recommended for Indian tractor operators for better contact between back of the body and backrest (Tewari and Prasad, 2000). This is to get better support in the seat while turning and monitoring implements attached behind the tractor seat.

4.10. Seat cushion

The seat surface should be cushioned (25–50 mm of compression is sufficient). The tractor seat with synthetic rubber foam cushion materials (thickness = 100 mm and $\rho = 70\,\mathrm{kg\,m^{-3}}$) and composite (layers of coir and medium density foam) seat backrest cushion material (thickness = 80 mm and $\rho = 47\,\mathrm{kg\,m^{-3}}$) was found to be the most comfortable for Indian operators (Mehta, 2000).

4.11. Seat adjustments

The tractor seat position should be adjusted vertically and longitudinally to accommodate most of the tractor operators. According to IS 12343 (1998), it can be adjusted longitudinally and vertically from its mid-position with a minimum of ± 25 and ± 30 mm and with an optimum of ± 100 and ± 50 mm, respectively. The 5th and 95th percentile values of popliteal height sitting of Indian male agricultural workers were 366 and 463 mm, respectively. Therefore, a vertical adjustment of 97 mm may accommodate 90% of Indian operators in the tractor seat. This meets the BIS recommended optimum value of ± 50 mm from mid-position. The 5th and 95th percentile values of buttock popliteal length of Indian male agricultural workers were 379 and 500 mm, respectively. Therefore, longitudinal adjustment of 121 mm in the tractor seat may accommodate 90% of Indian operators. Therefore, there should be longitudinal adjustment of ± 60 mm from mid-position in the tractor seat.

5. Conclusions

The following conclusions can be drawn from the study:

(1) The anthropometric considerations should also be given due importance in deciding seat dimensions and their adjustments for tractor seat design for operator's comfort.
(2) The anthropometric dimensions, i.e. popliteal height sitting (5th percentile), hip breadth sitting (95th percentile), buttock popliteal length (5th percentile), interscye breadth (5th and 95th percentile) and sitting acromion height (5th percentile) of agricultural workers should be taken into consideration for design of seat height, seat pan width, seat pan length, seat backrest width and seat backrest height, respectively, of a tractor.
(3) The important dimensions recommended for the tractor seat based on anthropometric considerations of Indian operators are as follows:

- Seat height: 380 mm
- Seat pan width: 420–450 mm
- Trapezoidal seat backrest width: 380–400 mm (bottom), 270–290 mm (top)
- Seat length: 370 ± 10 mm
- Seat backrest height: 350 mm

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