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Vol. 11(47), pp. 4850 -4856, 24 November, 2016
DOI: 10.5897/AJAR2016.11035
Article Number: 897AC0761850
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Tractor operator anthropometric profile of the Brazilian Northeast State

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Received 23 March, 2016; Accepted 28 September, 2016

Due to the agricultural modernization,some crops already have their production process fully realized byfarm machinery. In order to enhance operational performance and reduce both fatigue and accident risk, itis fundamental to provide a safe and adequate working environment. Therefore, the working station must be adapted to the operator's anthropometric and mechanical characteristics. The present study aimed to evaluate the anthropometric profile of agricultural tractor operators in the macro-region of Ceará state's west coast, and check whether the tractors are up to ISO and NBR ISO standards as well as to assess the risks of heart disease to which these drivers are exposed from epidemiological studies. The experiment was conducted in nine farms located along the macro-region of the Ceará state's west coast, in the following cities, Itapipoca, Itarema, Acaraú and Camocim with 39 agricultural tractor operators. For the samples, statistical analysis calculated were the minimum and maximum found values, mean, standard deviation, coefficient of variation, the amplitude and the percentiles of 5, 50 and 95%. The operators of the macro-region of the Ceará west coast had a lower height average than both the national average of 1.73 m and the Ceará state mean of 1.69 m. From the ISO and NBR ISO standards specifications evaluated, it is possible to saythat the standards are either inadequate or partially unsuitable for the operators evaluated.

Key words: Ergonomics, safety in agriculture, agricultural tractor, anthropometry.

INTRODUCTION

Currently, Brazil isachieving high productivity levels in agriculture and manual labour is being increasingly replaced by farm machinery. The current agricultural sector requires the constant increase in both productivity and food quality, which makes companies to seek ways to improve the production system. Modern machinery is usually cited as the main way, and may have the following desirable characteristics, reduction in losses, better operation quality and better workstations.

When the workstation is not suitable, the operator cannot easily handle all tractor commands and is more susceptible to increased physical and mental stresses, which may increase the operational errors, accidents and the development of various occupational diseases may

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alsoreduce both the operation efficiency and quality.

According to Rossi et al. (2011), the farm machinery operation is a very stressful activity, most of the time the operator has long work shifts and is passive to undesirable weather conditions that may affect the operation itself as well as the operational productivity. To mitigate the harmful consequences, the tractor workstation must have the minimum conditions for the work to be performed in such a way that the driver is not exposed to both health and accident risks.

According to Pheasant (1998), the correct human scaling to the machine need to ensure that within the workstation there are enough space for any operator that may use the tractor. Regardless of physical characteristics, the operator must be comfortable and have an easy access to all tractor's controls for a proper operation.

Currently, regarding technological developments in agricultural machinery projects, there is a tendency related to ergonomics and safety aiming to improve working conditions and reduce both fatigue and accident risk. The optimization of ergonomic factors may play an important role in increasing efficiency of the human-machine system. According to Victor et al. (2002), anthropometric measurements are the most important considerations in designing ergonomically appropriate agricultural machineries.

There is no exact anthropometric standard for humans. In fact, is possible to realize a diversification of these standards as compared to people from different countries and the standards may also change within the same country.

In Brazil's case, besides the continental size, the country underwenta colonization process from different countries and Santos (1995) stated that the landscape separated the different ethnic groups, which may generate a significant physical difference between individuals. Oliveira (1998) argued that anthropometry plays a key role in the ergonomic context because it is possible for adequate operation of the workstation.

The workstation has countless variables related to its sizing, which impede an ideal model implementation that is fully compliant to the anthropometric diversity. Due the anthropometric variance, the operator station needs to be adjustable for the different driver who might work in the enterprise.

However, Schlosser et al. (2002) claimed that each operator has measures that could either fit or not in an ideal model, which makes it more difficult to project a coherent workstation. The projects of operating stations are sized from standards (ISO and NBR ISO) which are developed to ensure a national representation; however, the physical specificities of individuals from each region are not taken into account. Thus, different operators may not be appropriately fitted in as the specify limit that may or may not meet the individual needs. The correct way to check the driver's adjustment is testing and developing anthropometric profiles.

When the workstation is not suitable, the operator cannot easily handle all tractor commands and is more susceptible to both physical and mental stresses. This situation may increase operational errors, accidents and the development of various occupational diseases as well as may reduce both operational efficiency and quality.

Worldwide, many anthropometric studies have been conducted. Ghaderi et al. (2014) developed a harvester seat based on Iranian operators' anthropometric data. Mugisa et al. (2016) evaluated anthropometry to design labour-saving tools. Syuaib (2015) conducted an anthropometric study of farm workers in Indonesia in order to design novel farm tools and equipment.

The study aimed to evaluate the agricultural operators anthropometric profile in Ceará State and to verify whether tractors workstations are in accordance with both International and Brazilian standards (ISO and NBR ISO) as well as to assess the heart diseases risk that these operators are exposed to, from epidemiological studies**.**

MATERIALS AND METHODS

The experiment was conducted in nine farms located along the macro-region of the Ceará state's west coast, in the following cities, Itapipoca, Itarema, Acaraú and Camocim; these cities were chosen because of their large number of operators.

Prior to the data collection, all participating operators were informed about the survey content and methodology. To obtain the anthropometric profile, in each operator, 21 measurements (height, body mass, arms raised reach, height at eye level with the operator standing, height at eye level with the operator sitting, height at ear level with the operator standing, height at ear level with the operator seated, foot distance from the ground, hip width, hip circumference, waist circumference, height at shoulder level, distance from the foot to the knee, arm reach, forearm reach, sacral-knee, back length, back width, hand length, foot length and age) were done according to Kroemer and Gradjean (2005).

The operators were shirtless and wore shorts for the measurements. The measuring time was approximately 10 to 15 min per driver. The measurements were performed with measuring tape, rulers (linear and L format), digital balance, stadiometer, chair with right bottom and forms for the data collection. Measurements were carried out in two stages: the operator while standing and the operator seated (legs formed at 90° angle).

To determine the amount of operators required for sampling, the operational characteristic curve method was utilized (Equation 1) from which, it is possible to find the (d) value at 5% significance level.

$$d = \frac{|\mu - \mu_0|}{\sigma} \quad (1)$$

Where: d = sample number;μ = population mean;μ_0 = sample mean;σ = standard deviation.

From the 'd'value obtained, it was possible to find the minimum sample amount using the graph of operational characteristic curves (Montgomery and Runger, 2012). For the current study, the minimum amount of samples required according to the methodology used was nine samples, and the total amount acquired was thirty nine, which demonstratesthat the collected samples are representative of the total population.

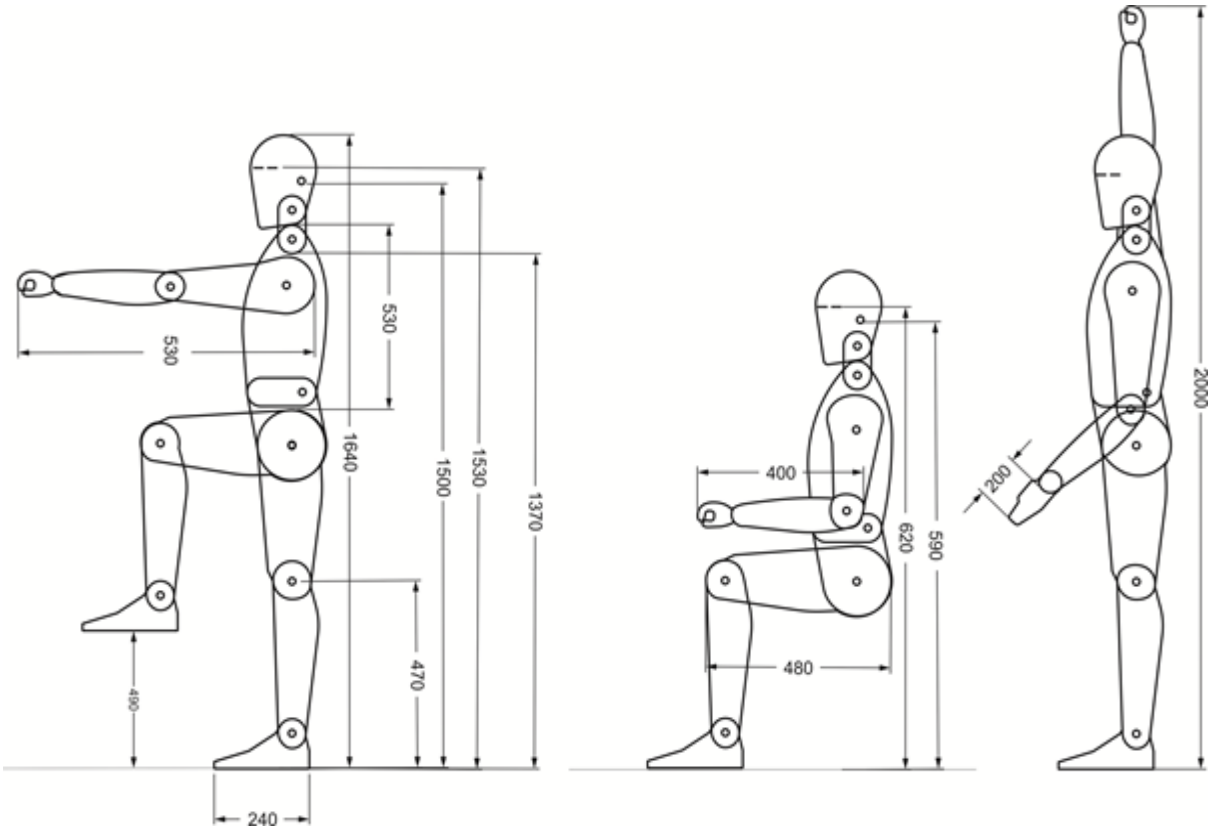

Figure 1. Average operator anthropometric profile of the macro region of the Ceará state's west coast in millimetres (mm).

For the samples, statistical analysis done were the minimum and maximum values, mean, standard deviation, coefficient of variation, the amplitude and the percentiles of 5, 50 and 95%, generating an anthropometric profile of agricultural tractor operators in the macro-region of the Ceará state's west coast.

The evaluation of obesity and the risk of heart disease was performed using the body mass index (BMI) method (Equation 2) and the waist-hip ratio (WHR) (Equation 3) through the gathered data.

$$IMC = \frac{m}{L^2} \quad (2)$$

Where:BMI = body mass index;m = body mass;L^2 = stature.

$$RCQ = \frac{ca}{q} \quad (3)$$

Where:WHR = Waist-hip ratio;Ac = abdominal circumference;q = hip circumference.

The standards utilized in the projects of operating stations, ISO and NBR ISO standards, were chosen for the operation station scaling.

The selected standards were as follows: NBR ISO 26322-1: Agricultural and Forestry Tractors - Safety Part 1: Conventional Tractors (ABNT, 2011a). NBR ISO 26322-2: Agricultural and Forestry Tractors - Safety Part 2: Small and narrow gauge Tractors (ABNT, 2011b). NBR ISO 4252: Farm Tractors - Operator workstation, access and exit - Dimensions (ABNT, 2011c). ISO 15077: tractors and machinery for agriculture and forestry: operator controls: actuating forces, displacement and their location (ISO, 1996). ISO 4253: Agricultural tractors: operators' seating accommodation: dimensions (ISO,1993). ISO4254-1: Agricultural machinery: safety: Part 1: General requirements (ISO, 2008).

After reviewing the standards, ten specifications which determine far-reaching measures were chosen, in order to be compared with the assessed operators' profile.

The evaluated specifications were as follows, maximum height of external controls from the ground, power take-off (PTO) external control, height of the cabin access, the first step above the ground height, longitudinal seat adjustment for the middle position, width total seat cushion (bottom), lumbar back seat length, lumbar backrest full width, driver foot reach and filler tank height.

RESULTS AND DISCUSSION

The 39 operators evaluated could perform all the necessary functions, although with limited access to certain tractor controls and limited movement during operation. Figure 1 shows the mean profile of the macro region of Ceará state's west coast operators.

The anthropometric profile (Table 1) showed that the agricultural tractor operators stature of the macro-region of Ceará state's west coast is less than both the national average of 1.73 m and the Ceará state average of 1.69 m according to the IBGE (2014), for the group aged 30-34

Table 1. Operator anthropometric profile of the macro region of the Ceará state's west coast in millimetres (mm) (body mass (kg) and age are not included).

Measures	Percentiles			Min.	Max.	Mean	Standard deviation	CV (%)	Amplitude
	5%	50%	95%						
body mass	55	71	89	53	90	73	9.97	13.65	37 kg
Age	23	32	45	21	52	33	7.32	22.23	31 years
stature	1540	1650	1750	1540	1770	1640	0.06	3.53	230
height at eye level	1430	1530	1610	1430	1660	1530	0.06	3.75	230
height at ear level	1410	1500	1580	1400	1630	1500	0.06	3.67	230
height at shoulder level	1300	1370	1450	1280	1540	1370	0.05	4.01	260
arms raised reach	1860	2010	2110	1830	2170	2000	0.07	3.53	340
foot – knee distance	420	470	510	410	520	470	0.03	5.57	110
hand length	190	200	210	190	220	200	0.01	4.52	35
forearm reach	360	410	430	360	490	400	0.03	6.53	130
arm reach	640	720	760	630	820	720	0.04	5.02	190
waist circumference	720	870	1050	710	1110	880	0.10	11.07	400
hip circumference	890	990	1080	800	1111	990	0.056	5.72	220
back width	420	470	520	390	600	480	0.04	8.78	210
back length	470	530	580	420	590	530	0.03	6.16	170
foot distance from the ground	410	490	550	380	580	490	0.44	9.16	200
hip width	310	470	580	290	590	450	0.09	10.59	300
sacral-knee	410	490	540	380	580	490	0.2	9.35	200
foot length	220	240	260	220	270	240	0.01	4.87	45
height at eye level (seated)	550	650	690	490	740	620	0.05	4.63	250
height at ear level (seated)	520	620	660	460	710	590	0.05	4.18	250

years.

Schlosser et al. (2002) reported that changes in anthropometric patterns can significantly occur within the same country (different regions) due the different ethnic colonization of each region. Therefore, the tractor workstation which has been designed according to specifications defined by national standards may provide an inadequate working environment for the operator due to the previous mentioned anthropometric diversity within the country.

According to the standards utilized in the present study, the external tractor controls should be located where the operator can activate them while remaining standing outside the hazard area between the tractor and agricultural equipment to be connected. These controls must to be at a maximum height of 1,800 to 2,000 mm from the ground. By analysing the following measurement, operator arms raised in the anthropometric profile, which is possible to observe that all operators are able to achieve these controls to a height of 1,800 mm, but the 5% of the total drivers has shorter range than 1.860 mm and they would not be able to reach the controls on the limit of 2,000 mm high.

According to the rules, there must be an external control located where the operator is able to switch the PTO off of the tractor and this device height must be up to 2,000 mm in height from the ground. However, whether the device is located after 1,860 mm, would be inaccessible to the 5% of the profiled operators previously mentioned and may cause serious accidents with the PTO, even lead to death of the victim.Handrails and the filler tank must be placed at a maximum height of 1,500 mm from the ground, which would be accessible to all operators, bearing in mind the operators' lower reach with arms raised at 1,830 mm.

Tractor accesses as steps and handrails must be only provided whether the vertical height of operating platform is 550 mm above ground level. By looking at the measured distance from the ground to the operator foot (leg lifted) it is possible to argue that the steps are not accessible to all operators as 50% of the studied operators have a 490 mm range which indicates they do not reach the minimum range of 550 mm. In order to access the tractor the operators need to raise the leg at an angle greater than 90° which, according to Silva et al. (2005), is harmful due the recommended angle range should vary from 45° to a maximum of 90°, and the closer to 45° the better the comfort when climbing. Couto (2008) reported that approximately 20% accidents in agriculture are related to tractors, of which 54% are minor accidents due either to inappropriate equipment conditions or the safety items not suitable for the operator. For instance, the large distance between the first step and the soil may cause imbalances and may lead to injury.

According to the standards, the operator's foot range is defined by a hemispherical radius of 800 mm starting from the seat cushion front edge, with the seat in its central position. The maximum range obtained in the studied operators' profile (when the seat accommodates the entire hip and thighs) is 570 mm, having 95% of the profiled operators with 510 mm radius range. The results indicate that the closer the pedals to the limit of 800 mm, the greater the operator challenges in accessing it. In order to reach the pedals, the operator must protrude forward the seat which may generate an injury due to poorpostureandmayreducetheoperational productivity.

The longitudinal seat adjustment for the middle position can range from a minimum of 75 mm to a maximum of 100 mm, which may increase the operator reach facilitating the both feet and hands access. However, for the profiled operators, the feet would not reach 800 mm radius still, but about 670 mm bearing in mind the maximum seat adjustment. Therefore, the operator may not have full access to the pedals, depending on the arrangement made by the manufacturer.

The vehicle's seat should provide the operator a comfortable controlling posture, appropriate vision and safe access to different pedals and controls. Correct sitting posture has been acknowledged as an important factor for the prevention of musculoskeletal problems (Cranz, 2000). According to the standards, the seat cushion total width must be at least 450 mm. However, 31% of the evaluated operators' back widthhavevalues above 450 mm, reaching up to 580 mm. Therefore, a small seat can cause immense discomfort, especially due to the seat arms.

Kroemer and Gradjean (2005) reported that the backrest length should be sufficient to support both the sacrum area and lower back areas; however, a high backrest length may also be unfavourable because it creates movement limitations of the operators' back and shoulders.

According to the standards, the backrest length is at least 260 mm and there is no prescribed maximum value. The operators' backs average length was 530 mm, so standard accommodates the minimum value less than a half of the length of the operators' back. The lumbar backrest width is at least 450 mm, the operators profile average is 480 mm, up to a 600 mm maximum, which shows that due the high body mass, the operator does not fit in the minimum limits specified for the seat width both the cushion and the lumbar back. Ghaderi et al. (2014) affirmed that this condition may lead to both pain and discomfort and tend to increase the risk of musculoskeletal problems.Regarding to the BMI results, it was observed that none of the operators presented obesity classes II and III, but 21% of the operators presented obesity class I (Figure 2).

Regarding weight, 30% of the operators are at proper weight, 49% are in a pre-obesity and 21% are in obesity class I which is an alarming fact. According to Mendonça and Angels (2004), cardiovascular risk factors are intrinsically related with obesity and these risks may be enhanced by excessive physical efforts. Additionally, Larsson et al. (2002) presentedthe obesity decreases quality of life and life expectancy (KOCH, 2011). Kroemer and Gradjean (2005) stated that overweight may cause worse damage because physical efforts become even higher for overweight people as compared to normal weight operators.

According to Sorof et al. (2004), the body overweight is one of the factors that increase hypertension risk and the increasing obesity rate is becoming a major public health problem worldwide (Kelishadiet al., 2014; Cavaco et al., 2014).Operators in the macro-region of Ceará state's west coast are usually young, having a 33 year-old population average, however the following measure, waist circumference had high values, an average of 87 cm, reaching up to 111 cm, which are worrying values because the abdomen fat is usually associated with chronic diseases (WHO, 2000).

Pereira et al. (1999), in a study conducted in Rio de Janeiro, showed that men with a 95 cm waist circumference had a high predisposition to high blood pressure and among the operators of the Ceará West Coast, 25% have higher waist circumference values than 95 cm.The operators' waist-hip ratio (Figure 2) showed that 79% of the operators may be at moderate to very high heart disease risk and only 21% are at low risk.

The high values found at BMI and WHR tests are representative of the entire macro-region of the Ceará west coast, which indicates a public health problem in the region. Therefore, awareness campaigns should be carried out in the region due to the high number of heart disease and other diseases related to obesity. Operators with overweight, especially with abdominal fat, are more likely to cardiovascular risk diseases and consequently may have a higher death risk if diet changes are not taken (Rezende, 2006).

According to Cabrera and Filho (2001) and Mendonça and Angels (2004), weight maintenance and a healthy diet are extremely important for the prevention and/or the control of cardiovascular disease in operators.

Conclusions

1. The operators of the macro-region of the Ceará west coast had a lower height average than both the national average of 1.73 m and the Cearástate mean of 1.69 m.
2. From the ISO and NBR ISO standards specifications evaluated, it is possible to argue that the standards are either inadequate or partially unsuitable for the operators evaluated.
3. According to both methodologies, the body mass index (BMI) and the waist-hip ratio (WHR), the evaluated operators were highly predisposed to heart diseases, as 70% of the operators are above the appropriate weight

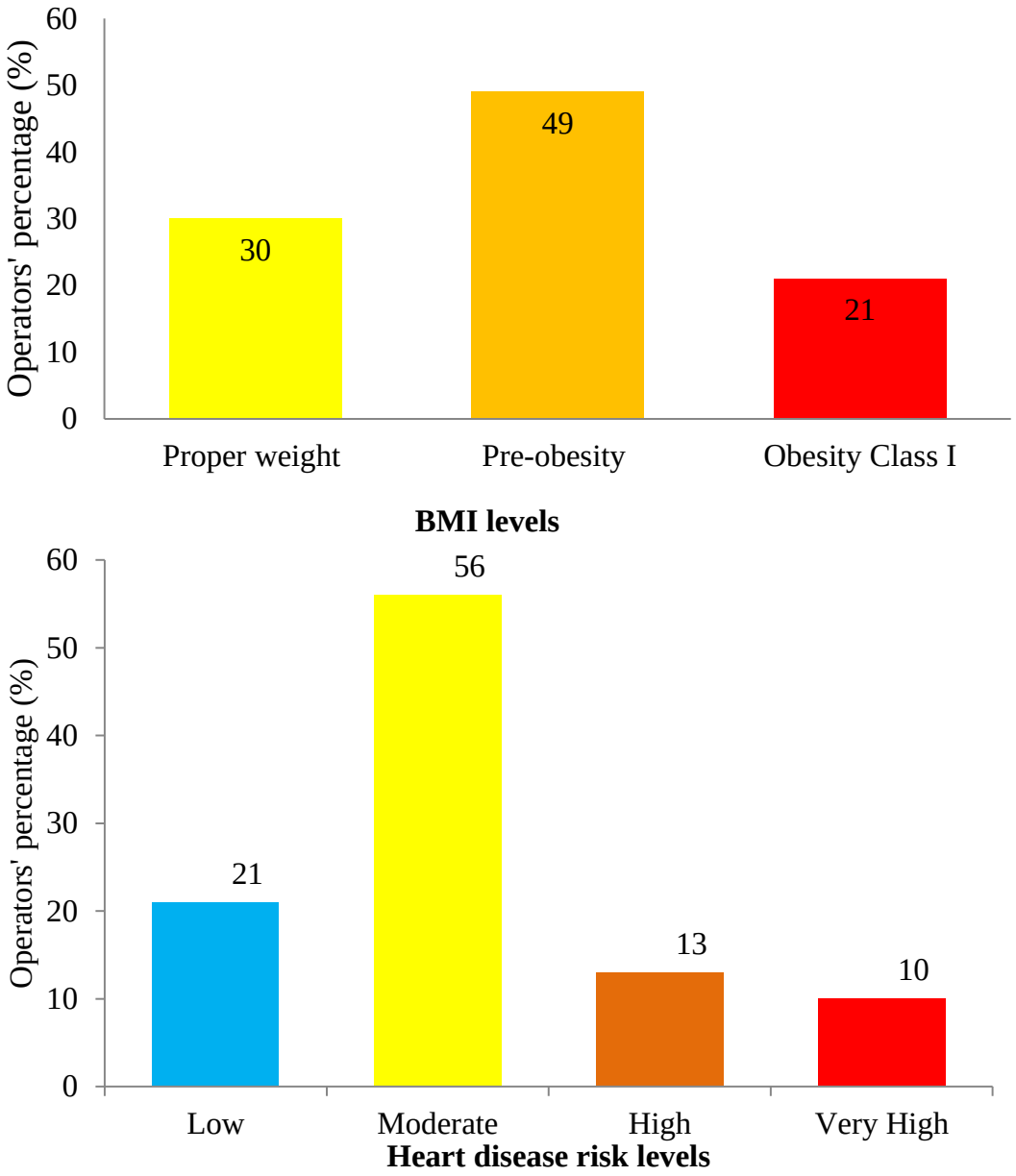

Figure 2.BMI and WHR results in percentage for tractor operators of the macro region of the Ceará state's west coast.

and 79% had moderate to high risk for heart disease onset.

Conflict of interests

The authors have not declared any conflict of interests.

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