

AN INVESTIGATION INTO THE ERGONOMICS OF TRACTOR SEAT POSITION

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Abstract

Considerable research has been carried within the automotive and trucking sector in order to provide an optimum driver or operator seating position. There is little available data for the agricultural sector, this combined with a high number of reported lower back problems, associated with agricultural workers, in particular tractor drivers, has been the driving force behind this specific area of research. The ergonomic layout of a typical tractor cab has been critically examined in order to establish the effect of repetitive working practices on operator stress levels and muscular injury. Three student volunteers were selected in order to obtain a range of data specific to body size. In order to carry out this investigation the services of a professional physiotherapist needed to be engaged in order to monitor the effects on each of the volunteers' health. The outlined results proved that when an operator is sat in a too close position to the machine controls and pedals, considerable muscular discomfort is caused to the upper and lower legs and the lower back. Operator concentration increased when the driving; due to the operators stating they were more concerned with safety and were aware they sat in a compromising position. Had the operators been unaware they were taking part in the experiment all stated they would not have been concerned with safety aspects and carried on regardless. The results for the research are presented in table form and clearly identify the potential for potential long term health problems developing.

Key words: ergonomics, tractor seat position, health and safety.

INTRODUCTION

A Seat position and ergonomics is a vital factor in choosing a machine to use when using it to do a repetitive job usually on a daily basis [1]. Seat positioning is a factor which requires a considerable amount of investigation as to whether it affects operator performance and operator fatigue. This is in relation to driving Agricultural vehicles, when operators are using said machines for regulated periods of time using a number of common tasks [2]. Using three test subjects this investigation will seek to prove the value of a machine having a variable seat position. Using the said three test subjects for the investigation 'Does Seat Positioning Affect Operator Performance and Fatigue?' it should be possible to determine the long term and short term effects of bad cab ergonomics on the operator. The specified positions of the seat are set in the following positions: too high, too low, set right for the operator.

There is no doubt the importance of Ergonomics in relation to safety within the agricultural industry, but there is a tendency on the part of some ergonomists to assume that a machine will be safe just because it is designed on certain ergonomic principles. This assumption can be often justified – but not always [3]. Agricultural Vehicles have been pushed into the spotlight in the past fifty years due to the diminishing of manpower and entering into the era of the 'Mechanised Industry', it is no longer a case of matching person to machine it is now perceived that one machine can be suitable for all users [4] or is this really the case? Is it possible for one machine to be selected to not cause long term/short terms discomfort to all its operators? [5]. Agricultural vehicles suddenly had to adapt, as they now perform more tasks, are used more regularly and have new purposes thus creating more controls for the specialist implements. All these new controls had to be fitted into cabs all the while creating a

comfortable environment for the operator who was now spending up to twelve hours a day in a machine [6]. This investigation is relevant to contractors, farmers and machine operators that spend almost every day of the week performing mundane and relentless tasks from tractor cabs.

MATERIAL AND METHOD

Three test subjects were chosen for the investigation to have an example of one type of each male (as all subjects had to be the same sex to create a fair test,) an average eighteen year old male, a taller than average seventeen year old male and a shorter than average seventeen year old male. An average male is described as the sample of males within the general population taken for analysis; the average is derived from the measurements taken from the specific anthropometric data [7]. All participants in the test had to be born in the same year but their age varied slightly as this would create a benchmark situation for the test. A physiotherapist judged the subject's suitability for the tests before the examination took place. Three students were selected who volunteered to assist in the collection of data.

After discussions with the physiotherapist and test subjects it was decided fifteen minutes would be sufficient to gain readings and show preliminary muscle damage and Repetitive Strain Injury (RSI) complaints. After fifteen minutes the Straight Leg Raise (SLR) would be dramatically affected either way (showing and increase in the SLR or a decrease in the SLR) this would give good data [8].

For the driving experience a set route was drawn up which tested driving skills in real life situations; the route chosen made full use of the College campus and public roads, plus a practical exercise.

Each student was subjected to a preliminary examination conducted on body charts. Each subject had to ensure that they had no ongoing complaints from such problems as RSI pains, muscular discomfort in the back, legs or neck areas and skeletal (joint) pain. On-going complaints of RSI would affect the current results this is because RSI pains can last for; in some severe cases several years it may not always be diagnosed until the latter stages of its development [9]. This was why it was

important for the physiotherapist to establish that the subjects were not suffering unknowingly with RSI pains.

Each subject had to take part in the SM test repeatedly pushing the clutch up and down for fifteen minutes in each seating position; a body check along with a SLR had to be conducted before and after each test to establish a change in range of movement in each subject's legs.

All seat positions, TCP, OP and TFP, had to take into consideration the three working areas of Ergonomic design:

- The Immediate work area;
- The Intermediate work area;
- The Outer work area.

Each set of controls and devices has their own work area these three areas are applied to any situation not just tractor and vehicle cabs. They are used daily by ergonomists to establish the most common problem areas [10]. (Most problems are mainly discovered in the immediate and outer work areas, this was due to the over and under reach of operators' limb capabilities [11].

All results were recorded in tabular format, video evidence was taken of SM test to view for further analysis, and in addition still photos were taken of the different leg positions of each test subject. These were taken so the physiotherapist could establish where the different pressure points amalgamated together or whether they moved position.

The driving situation test had to be conducted on a different day so the previous SM results didn't interfere with the current results required. The seating positions were again set up in the following positions, too close, too far and optimum for the operator. A route was then set up that involved road driving, on campus driving and driving track driving plus one simple task hitching up a trailer; It is important that the driving was as real to life as possible as MSD's and RSI concerns caused by long term driving make up 75% of patient complaints to GP's in the year 2000 [12]. Drivers used to be a commodity for businesses as manpower was diminishing, but now due to more comfortable machines coming into operation more people are willing to drive these long and demanding hours [13] thus it was important that this test was true to real life.

RESULTS AND DISCUSSIONS

Table 1. Cab Measurements (average size person)

| Seat Position | Pelvic Bone to Steering Wheel Console (CM) | Centre of Stomach to the Centre of the Steering Wheel (CM) | Pivotal Joint of the Elbow to the Gear Controls (CM) | Straight Leg Raise Score Left Right |
|---------------|--|--|--|-------------------------------------|
| Before Test | | | | 57° 50° |
| Optimum | 40.5 | 20.2 | 20.5 | 56° 45° |
| Too Close | 37 | 17 | 17 | 31° 50° |
| Too Far | 42.4 | 22 | 22 | 40° 44° |

This table demonstrates all the different measurements taken of the first test subjects positioning in the Same 110 Cab. The left leg SLR score at the worst was affected by 26° in the TCP, this is a drastic result according to the Physiotherapist showing that the pain felt must have been extreme, research conducted into SLR's and anthropometric data suggests that a drop in more than 10° in an Active ROM SLR is an excessive reading [14]. A difference of 3.5 cm is only small between the OP and the TCP yet this showed the most impressive result. The right leg in the SLR was only affected minimally as the right leg was not in use in the test. This would suggest though, that pain travelled along the lower back to the right leg in the sciatic nerve, the longest nerve in the body that travels from the back of the pelvis along the buttocks and down both legs [15].

Table 2. Cab Measurements (taller than average size)

| Seat Position | Pelvic Bone to Steering Wheel Console (CM) | Centre of Stomach to the Centre of the Steering Wheel (CM) | Pivotal Joint of the Elbow to the Gear Controls | Straight Leg Raise Score Left Right |
|---------------|--|--|---|-------------------------------------|
| Too Close | 38.5 | 16 | 11 | 61° 51° |

The left leg Active SLR dropped by 13° and the right leg dropped 9°. As Sarfit and Wood (1989) [14] suggest a 13° drop is again a very excessive reading showing a positive result. A negative ROM result occurs when an Active SLR reading is a higher degree after exercise than it was before [16].

The position the second subject is in is a highly dangerous situation, the knee is touching the steering wheel in the clutch release position and

the quadriceps muscle is touching the steering wheel in the clutch depressed position. The muscles are extremely over tightened; the fulcrum point is taking a drastic pressure increase in both release and depressed position this is often the cause of many cartilage problems in the future [17]. This subject cannot achieve a closer seated position due to the size of the cab, they are one centimetre and a half away from the average males closest seated position. The seat in this particular cab cannot accommodate a person of this size in a comfortable position.

Table 3. Cab Measurements (smaller than average size)

| Seat Position | Pelvic Bone to Steering Wheel Console (CM) | Centre of Stomach to the Centre of the Steering Wheel (CM) | Pivotal Joint of the Elbow to the Gear Controls | Straight Leg Raise Score Left Right |
|---------------|--|--|---|-------------------------------------|
| Too Far | 40 | 22 | 20 | 60° 30° |

The smaller than average male had a negative Active SLR result the left leg went up by 19°, this could have been cause by a previous injury making the muscles weaker which causes them; instead of tightening to relax, this is know an overuse injury and happens after an injury when a muscle has not had chance to repair itself properly [18]. In the depressed position the subject's entire body has gone rigid the resistance pushing up and the force pushing down will be immense on the not only the fulcrum point but the ankle as well. The ankle now becomes a Ground Reaction Force (GRF). The GRF is indicative of the body positioning and dynamics and acts as the ground point of the second class lever [19]. This was a compromising position for the subject both in concepts of safety and comfort.

The HP Score was most affected after the TFP. The OP score was the highest result; as this was a test situation it is often common for a subject to suffer from nervousness during the first testing procedure until the process is known thus affecting the results [20]. The overall best score was achieved after the OP, showing that increased concentration levels and better time perception (speed at which subject registered the oncoming hazard in the test) are achieved when the operator is comfortable and not feeling any pain [21]. The improved

concentration levels have also been achieved overseas in active concentration tests (also computer based similar to the HP test) performed after long stretches of driving periods [22]. The biggest drop was in the TFP for the smaller than average male. Surprisingly the taller than average male achieved very similar scores.

Table 4. hazard perception (average size driver)

| Subject | Hazard Perception Test Score Before Analysis | Hazard Perception Test Score After Optimum Position | Hazard Perception Test Score After Too Close Position | Hazard Perception Test Score After Too Far Position |
|---------------------------|--|---|---|---|
| Average Male | 67% | 72% | 61% | 50% |
| Taller Than Average Male | 67% | 70% | 70% | |
| Smaller Than Average Male | 70% | 89% | 80% | 38% |

Table 5. Hitching and un-hitching trailer

| Seat Position | Time To Hitch Trailer | Attempts To Hitch Trailer | Time To Drop Of Trailer (mins) | Attempts To Drop off the Trailer |
|--|-----------------------|---------------------------|--------------------------------|----------------------------------|
| Average sized person; optimum position | 1.35 | 1 | 1.40 | 1 |
| Average sized person too Close | 2.11 | 2 | 2.07 | 1 |
| Average sized person too Far | 1.57 | 1 | 0.22 | 2 |
| Smaller than average too close | 2.05 | 2 | 1.44 | 2 |
| Smaller than average to far | 1.37 | 1 | 2.54 | 3 |
| Taller than average to close | 1.50 | 2 | 2.05 | 4 |

The seat positions were set the same again for the driving tests. This was important to establish an overall rounded result; the entire test has to give an equal result in terms of time, effort and fairness [23].

The amount of attempts to hitch up the trailer and reverse it back into the designated space, increased in both the TCP and the TFP interestingly the results show that it was harder to drop off the trailer in the too far position and harder to pick up the trailer in the TCP.

This result may have been due to increased blind spots in the TCP making it impossible to

keep the foot on the clutch whilst trying to view the pick up hitch; it was also harder to raise the body out the too close position to remove them from the cab. There was also a loss of throttle control causing the machine to jerk into undesired areas, ruining the pattern of reverse this was supported by a concept from motor vehicle drivers that in correct seat position cause loss of foot pedal controls [24].

Table 6. Effect on heart rate during hitching exercise

| Subject | Heart Rate Before | Heart rate optimum | Heart rate too far | Heart rate too close |
|--------------|-------------------|--------------------|--------------------|----------------------|
| Average Male | 102 | 139 | 136 | 140 |

As the table shows the average males heat rate rose to 140 BPM at the highest end of the scale. A normal average male's heart rate should rest between 70 to 80 BMP but this will naturally increase to 100 - 200 BMP (in a twenty year old) during excitement, activity or anxiety [25]. The subject had a high heart rate before the test this was due the subjects' trepidation about taking part in the investigation. This would explain the high increase to 140 BPM the higher the start BPM the higher the increase. Blood oxygen uptake has to increase by 200% to compensate for the high heart rates displayed in the table [26]. Anything above a 300% increase is dangerous and can cause cardiac arrest in an unfit male as the stress placed on the heart is too extreme, the results provide an indication of the relative stress placed on the subject's heart [27].

The additional comments for this table are written as described by the subject. The most areas in pain were in the too far seating position, yet the pain rating scale (NHS Foundation Trust) revealed that the most pain felt in each area was in the too close position. One of the most concerning points being the increased blind spots described in the too close position this is a highly dangerous situation to occur from incorrect seating.

Table 7. Pain rating (average size operator)

| Subject | Before Test | Optimum Seating Pain Register | Too Far Seating Pain Register | Too Close Seating Pain Register | Additional Comments |
|--------------|-------------|-------------------------------|---|--|--|
| Average Male | No Pain | No Pain 0/10 | Leg Area 3/10 Lower Back 2/10 Neck (Top of Spine) 2/10 | Leg Area 7/10 Lower Back 5/10 | Too far trouble with the gear control as with the clutch and throttle Too Close increased blind spots, difficulty with steering and indicator controls very awkward and painful |

CONCLUSIONS

According to Same Tractors the seat should be able to accommodate any drivers 'Stature and Personal Preference' [28] this was proven not to be the case.

The original Hypothesis has shown that Yes there is a correlation between seat positioning and the mental fatigue of the operator. The investigation has also proved definitively that seat position does affect the operator in terms of comfort, and long and short term health defects. Due to pain receptors in the brain this will undoubtedly affect the operator's performance, the operator loses the aptitude to take part in simple tasks effectively this is the cause of mental stress and loss of concentration for many an hour after the process has finished [29]. This correlation found has been supported in other sectors of the industry, where HGV drivers were tested for lower back pain in relation to seat positioning. It was found similar to this investigation that Transient (lasts less than one week) pain was discovered in the lower back when the seat was in a too close position [30].

The enquiry was successful in demonstrating the need for more adequate seating positions within agricultural vehicles as is has been discovered that the population is changing and therefore requires further seating specifications for the safe operation of all agricultural machinery.

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| List of Abbreviations | |
|----------------------------------|-------------------------------|
| BPM- Beats per Minute | RSI- Repetitive Strain Injury |
| ES- Ergonomics Society | ROM- Range of Movement |
| HP- Hazard Perception | SLR- Straight Leg Raise |
| KE- Kinetic Energy | SM –Static Motion |
| MSD- Muscular Skeletal Disorders | TCP- Too Close Position |
| OP- Optimum Position | TFP- Too Far Position |