Rotatruck Vs Standard Hand Truck

Comparative Assessment Report - April 2011

dorsaVi Pty Ltd / Pro-Active Medical Pty Ltd

Rotatruck Hand Truck Comparative Assessment Report

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Contents

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1 Executive Summary

The aim of this assessment is to provide a quantified and objective comparison between a standard hand truck and a Rotatruck Self Supporting Hand Truck, when undertaking the most common actions or activities associated with hand truck use.

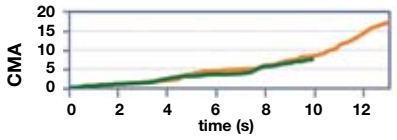
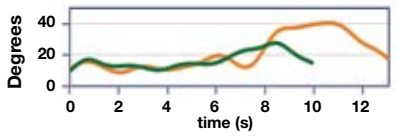
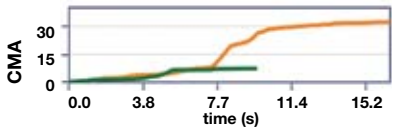
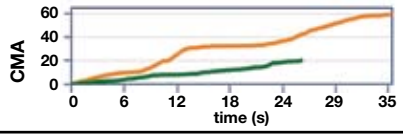
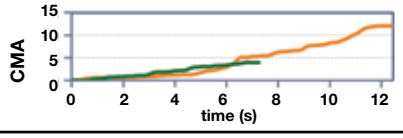
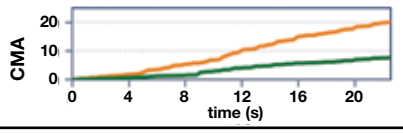
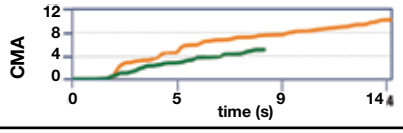
In industry hand trucks are commonly referred to in different markets as hand trolleys and/or dollies. For the purpose of simplicity this report will refer to them hereafter as hand trucks.

The Back Strain Monitor (BSM) was used to quantify movements and muscle activity of the lumbar spine while two workers carried out six frequently performed activities.

The parameters measured included muscle activity of the lower back (representing effort required to perform an activity), the degree of lower back flexion (how far the lower back had to bend to complete the task) and the time taken to perform a task.

The following table is a summary of the actions/activities assessed and their respective results achieved.

Key: Rotatruck Standard hand truck

	Typical Hand Truck Activity 105 Kg (230 Lb) Test Load	Cumulative Muscle Activity (CMA) % Maximum Voluntary Contraction	Reductions Achieved		
			Time	Effort	Bending
1A Muscle	**Load Pull Back** Pulling back the load ready for transporting or at way points such as doors or traffics lights etc.		**21%**	**59%**	**32%**
1B Movement		 **Flexion - Lumbar Spine bending (sagittal plane)**			
2	**Curb Negotiation** Ascending a curb face or a change in level.		**41%**	**78%**	
3	**Confined Space Operation** Entering and rotating 180º within a confined space such as a lift or storeroom.		**28%**	**65%**	
4	**Doorway Navigation** Navigating through a doorway with a self-closer.		**41%**	**67%**	**78%**
5	**Transporting a Load Around Obstacles** Navigating a loaded hand truck around a set of obstacles.		Marginal	**62%**	
6	**Vertical Maneuverability** Keeping a load close to vertical while rotating 360º.		**43%**	**51%**	

The results showed objective and quantifiable differences between the two hand truck systems for the activities assessed. For each of the six activities assessed, there were clear benefits seen when using the Rotatruck Self Supporting Hand Truck in each of the three domains assessed; muscle effort, flexion of the lower back and time efficiency.

2 Project Description

During April 2011, dorsaVi was engaged by Rotacaster to conduct an independent assessment of hand truck negotiation of 6 different activities commonly undertaken when using a hand truck. DorsaVi used its proprietary ambulatory measurement system (the Back Strain Monitor – see http://www.pro-activemedical.com for further details) to capture bio-physical measurements of a subject while they performed a simulation of their usual activities.

A load of 105kg (232 lb) was selected for testing as being a good mid range load, typical of what many distribution or delivery operators would encounter.

Two workers were assessed across 6 tasks with each task being repeated three times to improve reliability and validity of the results. Low back flexion (forward bending) and lateral flexion (sideways bending) together with muscle activity of the low back (erector spinae) were measured at 20Hz. Synchronized video footage was taken from two angles for illustration and validation of the recorded movement data.

Analysis of data was then conducted to compare the techniques and provide an objective picture of muscle activity and movements that were undertaken during the different tasks, and to assess whether one of the hand truck systems required less exertion than the other.

It should be noted that the results achieved in practice may vary dependent on the weight and configuration of the loads used.

3 The Environment

The assessment was undertaken at Rotacaster's factory in Newcastle, Australia (Figure 1) on the 20th April 2011.

Present on the day were Andrew Ronchi, Daniel Ronchi, Anthony Green (Pro-Active Medical Pty Ltd), Peter McKinnon and Chris White (Rotacaster).

Two workers were involved in performing the activities in a semi controlled environment. The six tasks were designed to mimic how a hand truck may be used in the workers normal daily activity. Care was taken not to increase the worker's normal activities and breaks were taken to simulate their normal work practices.

The floor surface was painted concrete and different factory equipment was used as props to simulate the typical task to be assessed.

Figure 1 - Factory setting where testing was performed

4 The Measuring Technology

New wireless technology enables bio-mechanical measurements to be taken during actual activities in semi-controlled or uncontrolled conditions for improved assessment of manual handling tasks.

The Back Strain Monitor (BSM) is able to quantify the movements and muscle activity of the lower back and present this data in comparative analysis to provide evidence as to the stresses acting on the lower back during different activities.

Four sensors adhere to the area to be assessed, in this case the lower back region. The sensors communicate wirelessly with a data recorder similar to a mobile phone (Recording and Feedback Device) and data can be viewed live on a PC screen and is recorded for retrospective analysis.

The recorded data is synchronized with video footage and can be presented in a report or in DVD format showing the comparative analysis as a video.

What is the Back Strain Monitor (BSM)?

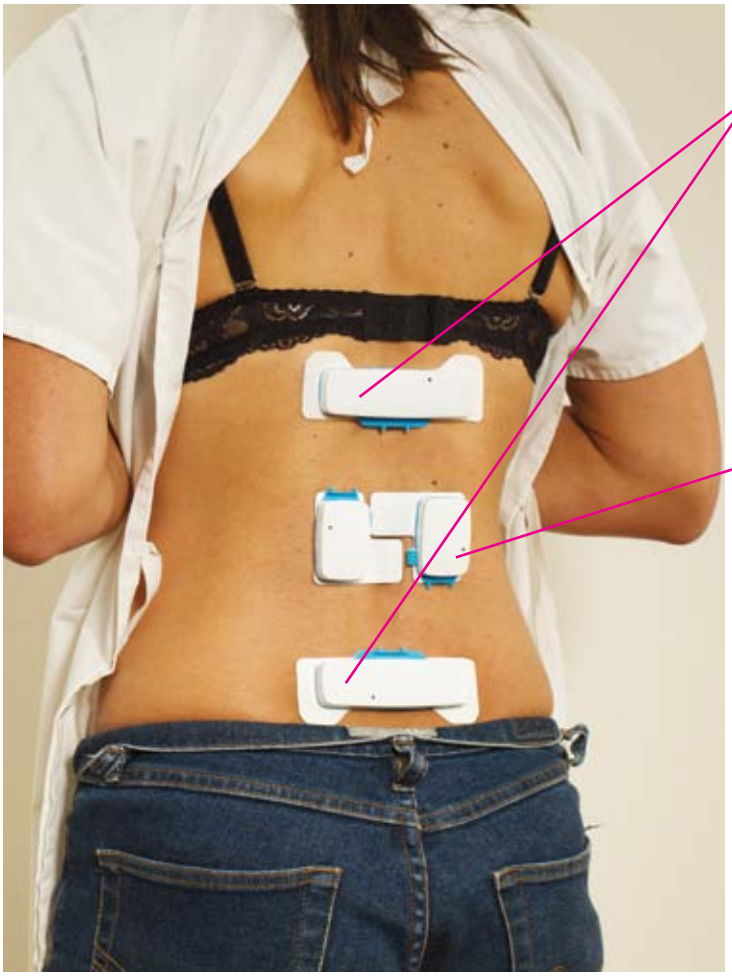


Figure 2 - Back strain monitor used for the assessment

Figure 2a - MDM Sensor

The MDM sensor measures movement via three tri-axial accelerometers and a gyroscope. The movement sensor is also capable of measuring accelerations, angular deviations, impact and vibration.

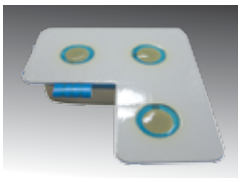


Figure 2b -
MDE Sensor & Electrode

The MDE sensor and electrode measure muscle activity and for this application, the sensors are placed on the erector spinae muscles of the lower back (at the level of L3).

Figure 3
Recording and
Feedback Device

The Recording and Feedback Device(RFD) wirelessly records movement and muscle activity data for up to 24 hours. The RFD is lighter than most mobile phones and is worn by the subject during the assessment.

5 The Hand Trucks for Comparison

To ensure an accurate comparison between the standard two wheel hand truck and the Rotatruck self supporting hand truck, both units were configured using identical aluminium component handles, frames, toes and 250mm (10”) pneumatic wheels. The pneumatic tires on both units were inflated and maintained at 275 kPa (40psi) throughout the tests. The handle used was a standard P loop handle allowing for movement of the hand or grip without release of the handle and single handed control where required.

The only difference or variable between the two test units was the patented Rotacaster self-supporting wheel base set-up utilizing the addition of two front Rotacaster wheels creating the self supporting wheel base of four wheels.

Figure 4 - Standard Hand Truck used for the assessment

Figure 5 - Rotatruck Self Supporting Hand Truck used for the assessment

5.1 Standard Hand Truck

Uses 2 x 250mm (10”) pneumatic wheels (Figure 4).

5.2 Rotatruck Self Supporting Hand Truck

The front two wheels use the Rotacaster multi-directional wheel system, with the back two wheels being the 250mm (10”) pneumatic wheels (Figure 5).

As the name would suggest, once the load is reclined into the transporting position, the Rotatruck Self-Supporting Hand-Truck is able to stand alone without having to be supported by the operator (or user).

6 The Activities & Results Summary

6.1 Load Pull Back

The pulling back of the load is a common and unavoidable activity associated with the use of hand trucks (Figure 6 & Figure 7). When pulling back a load, you have to lift the load up and over the supporting axle pivot point (the fulcrum - Figure 11, page 9). The center of gravity (COG) of the load will transition through an arc and will pass over the axle at which point the load can be balanced over the axle (Figure 12, 13 & 14, page 9).

The Rotatruck Self Supporting Hand Truck required 59% less pull back effort (Figure 10, page 8) to recline the load than the standard hand truck and there was 32% less lower back flexion (bending, Figure 9, page 8) to perform the pull back activity.

The Rotatruck can also be loaded in two phases, with the second phase being completed after pulling back a partial load into the reclined transporting position, thus further reducing the pull back effort required for a given load. However, for the purpose of direct comparison, only a full load pull back was used in this assessment

An additional factor to note is that the Rotatruck load pull back was 21% more time efficient than the standard hand truck.

From the Load Pull Back assessment performed, the Rotatruck Self Supporting Hand Truck required less muscle effort, less bending of the lower back and was more time efficient.

The Standard Hand Truck – Load Pull Back

Description of task:

When pulling back the load (Figure 6), the lever arm length from the fulcrum to the center of gravity of the load, is substantially greater than that of the Rotatruck. It's lifting arm is 67mm longer horizontally and 62.5mm higher vertically from the COG than with the Rotatruck resulting in significantly higher muscle activity to recline the load (Figure 10).

The horizontal distance between the front of the vertical load platform and the axle is 140mm on a standard hand truck and the load needs to be lifted through an arc based on a fulcrum (axle) height of 125mm (for a 250mm /10" wheel - Figure 13 & 14, page 9).

Figure 6 - Pull back load using the standard hand truck

The Rotatruck Self-Supporting Hand Truck – Load Pull Back

Description of task:

When pulling back the load with the Rotatruck self-supporting hand truck (Figure 7), the load pivots over the front 125mm (5") Rotacaster wheel instead of the larger 250mm rear wheel, thus lifting the load through a lower and shorter arc (Figure 14, page 9) than the standard hand truck.

The horizontal distance between the front of the vertical load platform and the axle is 73mm on a Rotatruck self-supporting hand truck and the load only needs to be lifted through an arc based on fulcrum (axle) height of 62.5mm (for a 125mm / 5" wheel - Figure 13 & 14, page 9)).

Figure 7 - Pull back load using the Rotatruck self-supporting hand truck

Due to the lower and closer proximity of the fulcrum to the center of load in the parked position, the balance point (point at which the COG is over the supporting axle) is reached without having to apply as much force, or to lift the load as high and to the extent of angle of recline required with the standard hand truck (Figure 14, page 9). This results in not only reduced effort, but also a reduced duration of applied force to bring the load to a balance point.

The other notable feature is the self-supporting nature of the Rotatruck. Once the load is reclined, the center of gravity of the load sits within the base of support (wheel base) of the four wheels removing the need for operator effort to support it.

6.1 Load Pull Back cont.

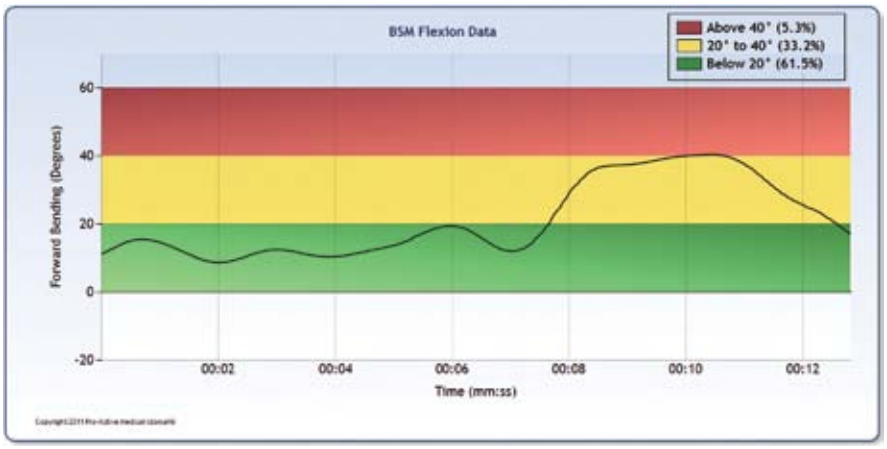


Figure 8 - Lower back bending when pulling pack a standard hand truck

In relation to the degree to which the lower back bends, when pulling back a standard hand truck in this assessment, 5.3% of the time is spent in >40ºflexion (forward bending) and 33.2% of the time is spent between 20-40º of flexion (Fig 8).

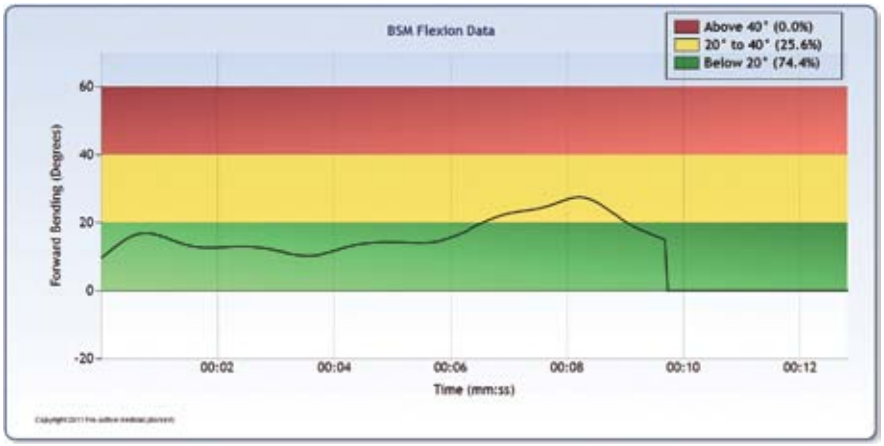


Figure 9 - Lower back bending when pulling pack the Rotatruck self-supporting hand truck

In relation to the lower back bending, when pulling back the Rotatruck self-supporting hand truck, 0% of the time is spent in >40º flexion (forward bending) and 25.6% of the time between 20-40º (Figure 9).

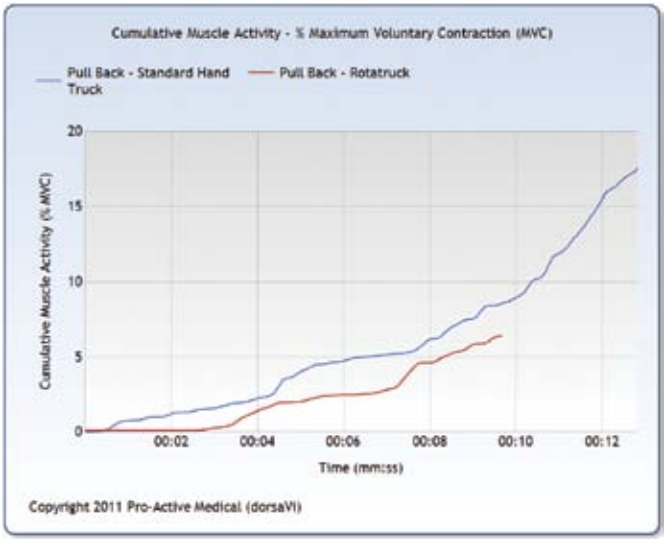


Figure 10 - Comparison of cumulative muscle activity for load pull back

Comparison of Cumulative Muscle Activity for the 2 hand truck systems during load pull back

Muscle activity of the lower back (erector spinae muscles at the level of L3) was recorded using electromyographic (EMG) electrodes that measure electrical activity of the underlying muscles. The Rotatruck Self Supporting Hand Truck required 59% less pull back effort (Figure 10) to recline the load than the standard hand trucks, based on the normalized cumulative muscle activity.

6.1 Load Pull Back cont.

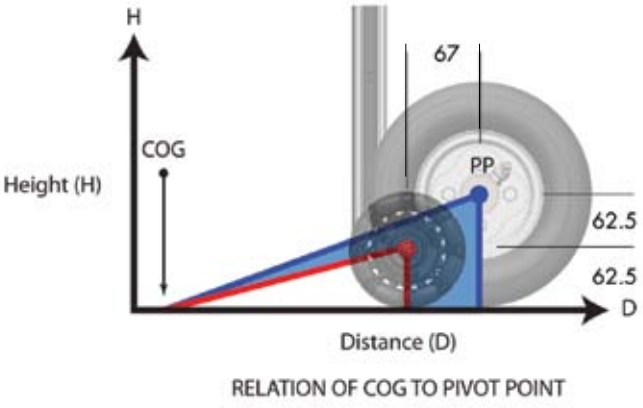


Figure 11 – The difference in the height of the pivot point between standard hand truck (blue) and Rotatruck (red)

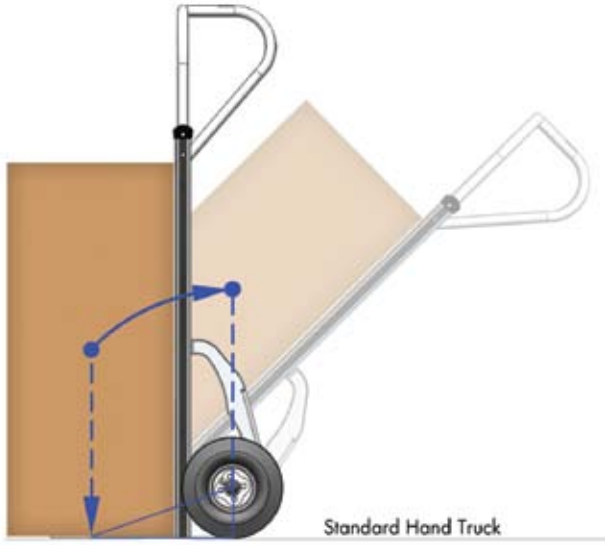


Figure 12 - Height of pivot point for a standard hand truck (125mm)

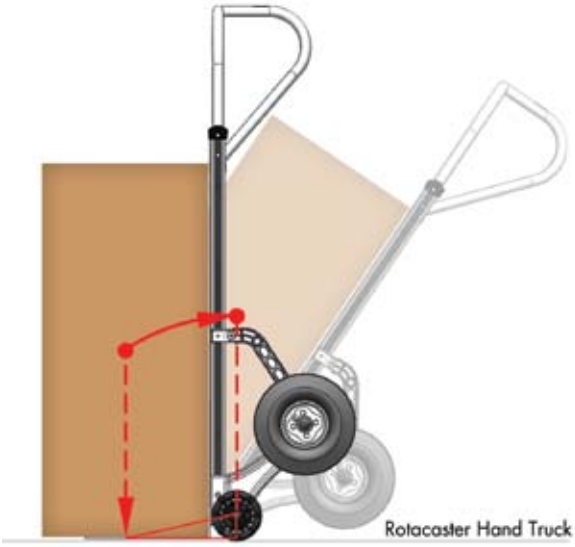


Figure 13 - Height of pivot point for the Rotatruck (62.5mm)

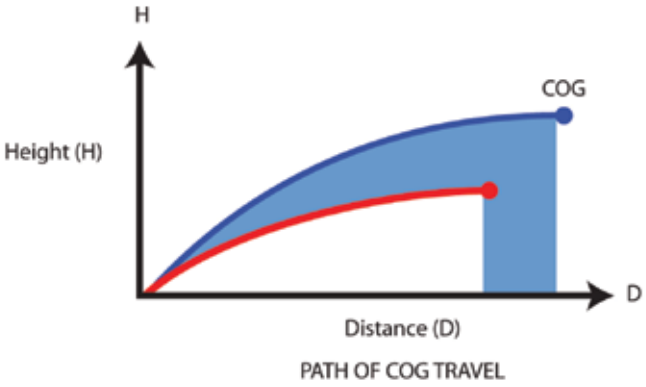


Figure 14 - The difference in arc of the lift for the standard hand truck (blue) and the Rotatruck (red)

6.2 Curb Negotiation

A common activity undertaken with a hand truck is to negotiate a load up a roadside curb (Figure 15). This can also be similar to the need to ascend a step or place a load onto a pallet.

During the assessment process, the average curb was measured to be 170mm (6.7") high. This activity was simulated by using a platform set at the above height and was assessed from the perspective where the operator was ready to continue in the forward direction.

The Rotatruck Self Supporting Hand Truck required 78% less cumulative muscle activity (Figure 19) to negotiate the load up the curb than the standard hand truck and the Rotatruck process was 41% more time efficient.

The standard hand truck – Curb Negotiation

Description of task:

With the hand truck loaded the worker approaches the curb with the standard hand truck directly facing the curb. The hand truck is then rotated 180 degrees. The worker steps up onto the curb and pulls the hand truck up the curb onto the upper level (Figure 15). The handtruck is once again rotated 180 degrees to allow the truck to be pushed forward to the designated delivery point.

Figure 15 - Curb Negotiation using the standard hand truck to pull load up a curb

The Rotatruck – Curb Negotiation

Description of task:

The worker approaches the same curb but does not need to turn to lift the hand truck up the curb (Figure 16). Instead the worker is able to elevate the front wheels of the Rotatruck to overcome the curb, and lever the load up the curb without the need to turn 180 degrees (either on the approach or departure from the curb).

Figure 16 - Negotiating a curb using the Rotatruck

6.2 Curb Negotiation cont.

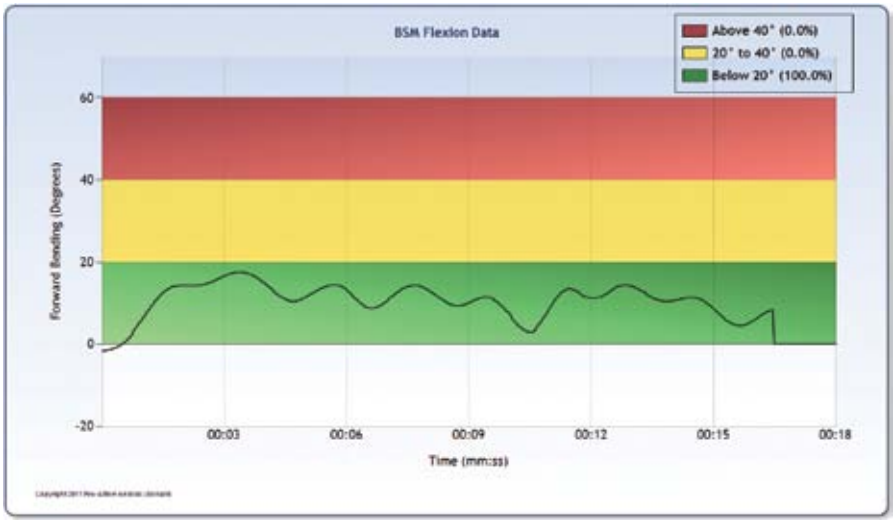


Figure 17 - Lower back bending when negotiating a standard hand truck up a curb

In relation to the degree to which the lower back bends, when negotiating a curb, the standard hand truck didn't require any flexion over 20º but took 17 seconds to complete the task (Figure 17).

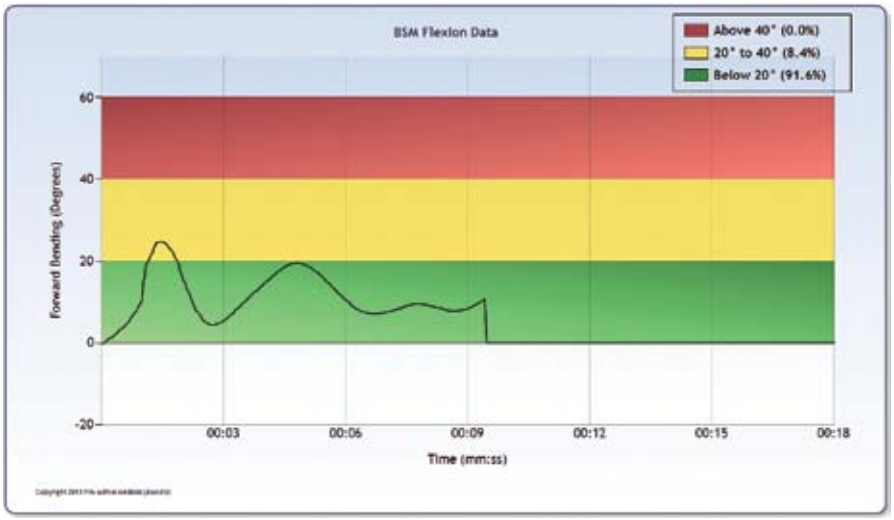


Figure 18 - Lower back bending data while negotiating the Rotatruck up a curb

In relation to the degree to which the lower back bends, when negotiating a curb, the Rotatruck required 8.4% of time in 20º- 40º flexion but no time over 40º (Figure 18).

Figure 19 - Pull up curb cumulative muscle activity

Comparison of Cumulative Muscle Activity for the two hand trucks systems during the curb negotiation

The Rotatruck Self Supporting Hand Truck required 78% less muscle effort and 41% less time to negotiate a curb when compared with a standard hand truck (Figure 19).

6.3 Confined Space Operation

Confined spaces, such as store rooms, corridors and elevator cars, often require rotation or change of direction with limited room to move. This was simulated within the factory as shown in Figure 20. The activity involved entering the space, rotating 180 degrees, parking the load for a short pause and then exiting the space.

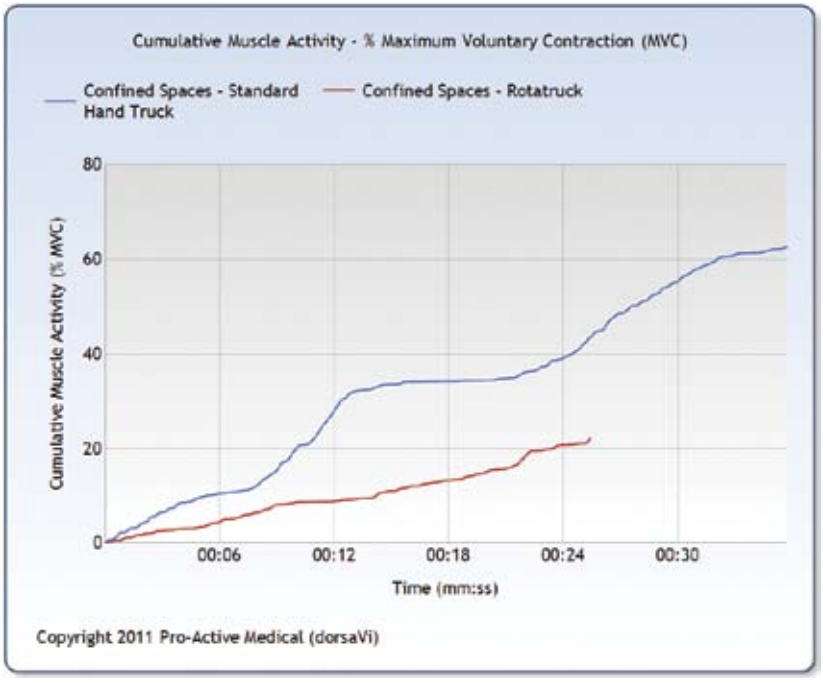
The Rotatruck Self Supporting Hand Truck required 65% less cumulative muscle activity (Figure 21) to operate the load through a confined space than the standard hand truck and the Rotatruck process was 28% more time efficient.

Description of task:

In the case of the standard hand truck the load had to be balanced by the operator while rotating and then parked in the upright position during the pause. Then the load had to be pulled back and then continue to exit the confined space.

In the case of the Rotatruck Self Supporting Hand Truck the operator was able to stand to the side of the hand truck during rotation as it was fully self supporting. In addition, it was not necessary to park the truck in the vertical position, removing the need to pull back the load before exiting.

Figure 20 - Example of operating a hand truck in a confined space



Comparison of Cumulative Muscle Activity for the two hand truck systems during during confined space operation

The Rotatruck Self Supporting Hand Truck required 65% less muscle effort to negotiate the hand truck through a confined space and was 28% more time efficient when compared with a standard hand truck (Figure 21).

Figure 21 - Cumulative muscle activity comparison of Rotatruck to standard hand truck for confined space operation

6.4 Navigating Doorways

Entering a building or sub premises often requires having to park the load while calling for electronic access (Figure 22b), and involves navigating closed doors, with or without, spring or automatic closers. In this task we have assessed the process of entering through a self closing door, requiring the operator to open the door and enter through the doorway and to continue in a forward direction.

The Rotatruck Self Supporting Hand Truck required 67% less cumulative muscle activity (Figure 25) to navigate doorways than the standard hand truck and the Rotatruck process, involved 78% less cumulative bending of the lower back (Figure 23 compared to Figure 24) and was 41% more time efficient.

Figure 22a - Rotatruck Self Supporting Hand Truck navigating a doorway

Figure 22b - Standard hand truck navigating a doorway

Description of task:

The worker approaches the closed door.

In the case of the standard handtruck the load is parked in an upright position while the doorbell is rung. Once the door is answered, the hand truck is pulled back into the reclined position and rotated to face away from the door so the operator can open the door with one hand while balancing the hand truck with the other. On opening the door, the operator then needs to hold the door open while balancing the load and pulling it through the doorway.

In the case of the Rotatruck Self Supporting Hand Truck, the operator was able to stand to the side of the hand truck while ringing the doorbell as it was fully self supporting. As such it was not necessary to park the truck in the vertical position thus removing the need to pull back the load before opening the door. With the Self Supporting Hand Truck supporting itself, the door can be opened without having to rotate the hand truck 1st and thus movement through the doorway requires less time and muscle effort.

6.4 Navigating Doorways cont.

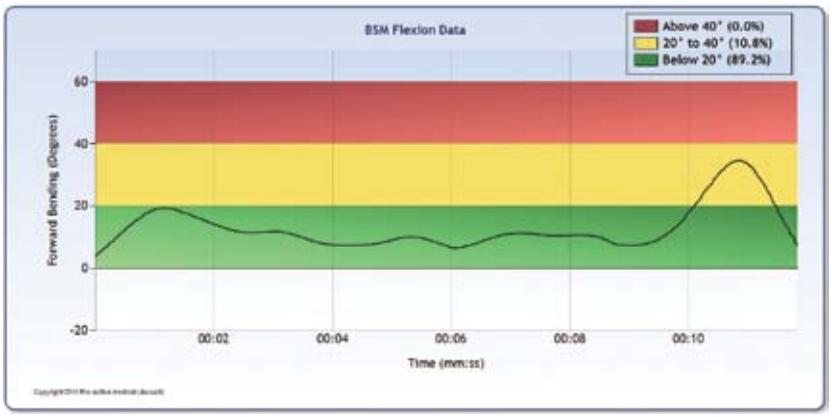


Figure 23 - Lower back bending data while navigating doorways with a standard hand truck

In relation to the degree to which the lower back bends, when navigating doorways, the standard hand truck required 10.8% of time in 20º-40º flexion and no time over 40º (Figure 23).

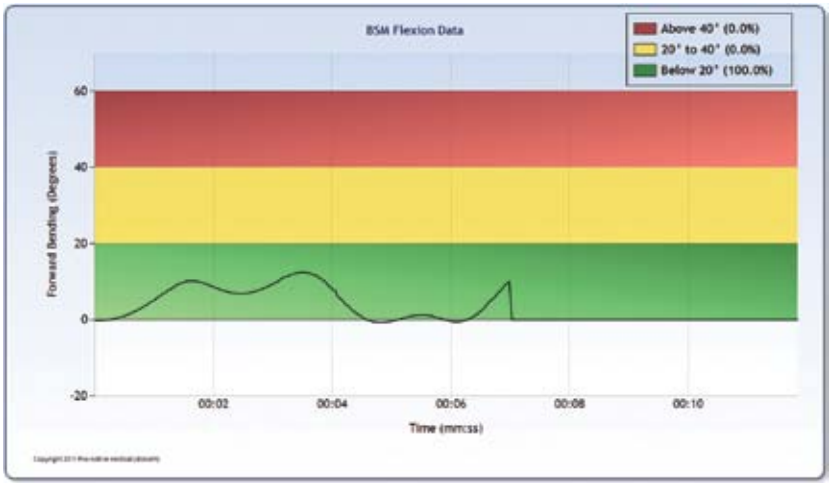


Figure 24 - Lower back bending data while navigating doorways with the Rotatruck

In relation to the degree to which the lower back bends, when navigating doorways, the Rotatruck required no time in 20º- 40º flexion and no time over 40º (Figure 24).

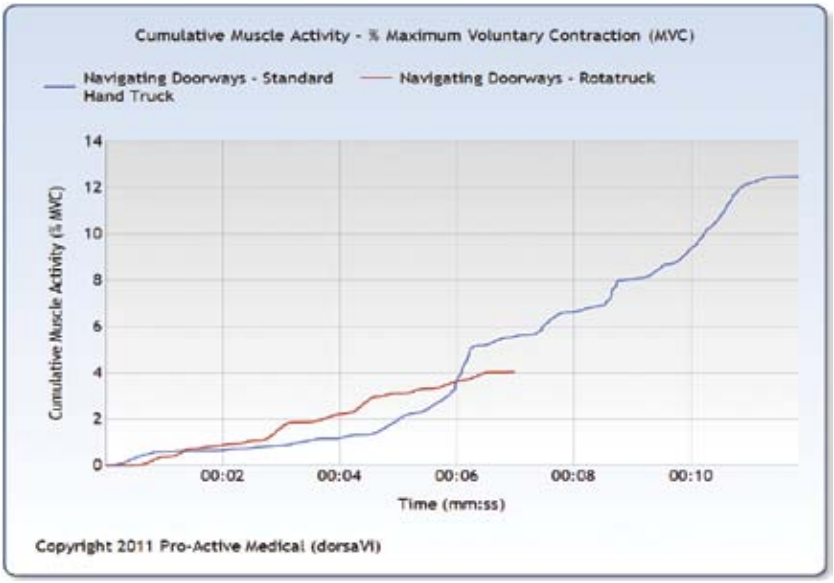


Figure 25 - Cumulative muscle activity comparison of Rotatruck to standard hand truck for navigating doorways

Comparison of Cumulative Muscle Activity for the two hand trucks systems navigating doorways

The Rotatruck Self Supporting Hand Truck required 67% less muscle effort to navigate doorways, and 78% less cumulative bending of the lower back and was 41% more time efficient when compared with a standard hand truck (Figure 25).

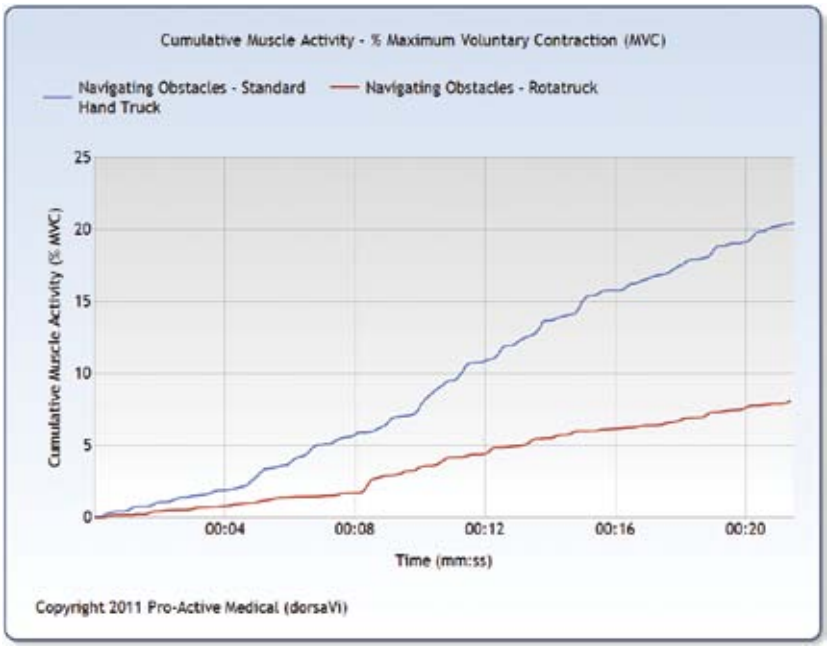
6.5 Transporting a Load Around Obstacles

Negotiating a standard hand truck around three obstacles was compared to moving a Rotatruck Self Supporting Hand Truck around the same three obstacles.

The Rotatruck Self Supporting Hand Truck required 62% less cumulative muscle activity (Figure 27) to negotiate obstacles than the standard hand truck and the Rotatruck process was marginally more time efficient.

Both the standard hand truck and the Rotatruck Self Supporting Hand Truck were negotiated around three obstacles. At all times both hand trucks were in the forward facing position and no pauses during the movement were observed (Figure 26).

Figure 26 - Negotiating Obstacles



Comparison of Cumulative Muscle Activity for the two hand truck systems navigating obstacles

The Rotatruck Self Supporting Hand Truck required 62% less muscle effort to negotiate the hand truck around obstacles and was marginally more time efficient when compared with a standard hand truck (Figure 27).

Figure 27 - Cumulative muscle activity comparison of Rotatruck to standard hand truck for navigating obstacles

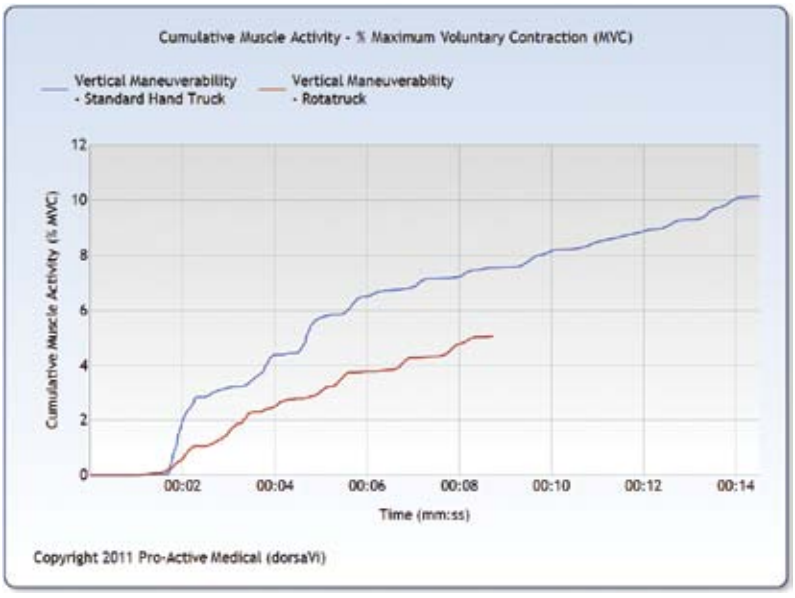
6.6 Vertical Maneuverability (Rotation) with a Load

The ability to vertically maneuver or rotate a load is relevant for many workers using hand trucks in their day to day work environment, especially within confined spaces. The assessment measured the time and muscle effort in performing a task where an operator balanced a load in a near vertical plane and rotated the hand truck to change direction.

The Rotatruck Self Supporting Hand Truck required 51% less cumulative muscle activity (Figure 29) in vertical maneuverability task than the standard hand truck and the Rotatruck process was 43% more time efficient.

Both the standard hand truck and the Rotatruck Self Supporting Hand Truck were rotated through 360º, while in a relatively vertical position (Figure 28).

Figure 28 - Vertical maneuvering of the load



The Rotatruck Self Supporting Hand Truck required 51% less cumulative muscle activity and was 43% more time efficient in vertical maneuverability task than the standard hand truck (Figure 29).

Figure 29 - Cumulative muscle activity comparison of Rotatruck to standard hand truck for vertical maneuverability

7 Conclusion

This assessment provides quantifiable and objective data on the use of a standard hand truck in comparison to a Rotatruck Self Supporting Hand Truck, when undertaking the most common activities associated with hand truck use.

During load pull back the Rotatruck Self Supporting Hand Truck required 59% less pull back effort to recline the load, 32% less lower back flexion (bending) and was 21% more time efficient than the standard hand truck. Curb negotiation with the Rotatruck Self Supporting Hand Truck showed a 78% reduction in cumulative muscle activity and was 41% more time efficient while negotiating the curb.

When operating in a confined space, the Rotatruck Self Supporting Hand Truck showed a 65% reduction in cumulative muscle activity and was 28% more time efficient. Doorway navigation through a standard street entrance had the Rotatruck Self Supporting Hand Truck showing a 67% reduction in cumulative muscle activity, 78% less cumulative bending of the lower back and was 41% more time efficient.

While transporting a load around obstacles, the Rotatruck Self Supporting Hand Truck showed a 62% reduction in cumulative muscle activity and was marginally more time efficient. Finally, vertical maneuverability with a load had the Rotatruck Self Supporting Hand Truck showing a 51% reduction in cumulative muscle activity to complete a 360° circle and was 43% more time efficient.

The results showed objective and quantifiable differences between the two hand truck systems for the activities assessed. For each of the six activities assessed, there were clear benefits seen when using the Rotatruck Self Supporting Hand Truck in each of the three domains assessed; muscle effort, flexion of the lower back and time efficiency.

7.1 Notes outside of scope:

- This comparative assessment addresses only lower back observations.
- This comparative assessment does not comment on the pricing, robustness and durability of the equipment used in the 'Rotatruck versus standard hand truck comparative assessment'.

7.2 Contributors

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