

## PowerMate – an Ergonomic Assessment

An Ergonomic Analysis of PowerMate L1 and PowerMate Pogo powered stairclimbers.  
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### Executive Summary

Stuart Ergonomics reviewed and analysed models PowerMate L1 and PowerMate Pogo for their ergonomic benefit to the operator. The powered stairclimbers were also compared to conventional methods of moving a load up and down stairs and vertically into a pick-up truck.

The theory behind PowerMate powered stairclimbers is that the operator is required to use much less force than conventional methods. This reduction in force translates into a safer working environment. In addition, the forces that are generated when using PowerMate would be functioning in biologically friendly directions. That is to say that the forces created in the body when using PowerMate are forces that the lower back is designed to bear, in contrast to the damaging forces created at the low back using conventional hand-trucks.

Two forces are recognised as having the potential to cause damage at the low-back, compression and shear. When the forces at the L4/L5 joint (low-back) exceed the recognised safety limits, the risk of injury rises exponentially. When the tissue fails i.e. the tolerance is exceeded by the demand, the vertebrae can fracture and the inter-vertebral disc can herniate. Depending on the magnitude of the force, the injury can be subtle and develop over time, as in chronic injury, or can occur suddenly and be considered an acute injury. Repeated stress can cause chronic injuries that will cause employees to be absent from work. It is estimated that approximately 80% of adults in North America will experience lower back pain in their lifetime. PowerMate seeks to help decrease that number amongst the product delivery population.

Peak forces were measured using a hand dynamometer, the Chatillon force transducer. This force transducer measured peak forces in both the tension, and compression directions. An empty steel box, provided by manufacturer LP International Inc., was used as the test load and attached securely to the different test hand-trucks. The forces were then measured during all relevant phases of operation of PowerMate and conventional hand-trucks. The results indicate that the PowerMate powered stairclimbers can

reduce the damaging forces by 5-10 times, when compared to the conventional hand truck. In fact, measurements indicate that using a conventional hand-truck will cause forces in the low-back that greatly exceed safety limits outlined by NIOSH.

PowerMate powered stairclimbers also have various features that will further reduce forces on the operator, these include:

- Hand breaks
- Wheel locks
- Breaking back the load

PowerMate is also capable of maintaining the load in a stable, stationary position while on flat ground or on a flight of stairs, which is a key safety feature as it allows the operator to maintain control at any stage of operation.

PowerMate is also recommended for moving loads vertically, such as the case when loading or un-loading from a pick-up truck. Lifting the test load vertically would exceed the safe lifting limit as suggested by NIOSH. Performing the same task using PowerMate produces forces equivalent to the break-back, which are well within safe operating limits. Conventional methods of moving a load up a flight of stairs will cause forces that have an incredible potential for injury to the lower back. Based on biomechanical modelling performed using the data sets and ergonomic observation, PowerMate is a safe alternative to conventional methods of moving heavy loads.

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### Introduction

Stuart Ergonomics was retained by LP International Inc. to conduct an ergonomic study of PowerMate powered stairclimbers (known as PowerMate Motorised Stairclimbing hand-trucks in North America) and provide a professional assessment of the safety and labour-saving benefit of a number of Powermate models.

The purpose of this study was to validate claims that PowerMate will reduce the risk of injury while moving loads up and down stairs. The study was also performed to assess various features that PowerMate comes equipped with.

In the past the only way for a load to be transported up a flight of stairs has been for one or more people to expend energy physically relocating it. This has been accomplished using a two-wheel dolly to pull it up one stair at a time, or to pick it up and carry it up the flight with at least one person having to walk backwards.

LP International Inc. developed a powered truck which will move a load using reduced operator effort. In addition to the stair-climbing function of PowerMate, it can also function as a tail-lift and some models are also capable of converting to a stable four-wheel dolly for extended flat-surface transportation.

### Background

PowerMate powered stairclimber is designed to reduce the amount of effort a worker must exert to move a load. PowerMate is also designed to reduce the potentially damaging forces on the spine. There are two forces that are recognised as having the potential to cause damage to the lower back.

#### **Compressive Force**

The first is compressive force. Compressive force is defined as the movement of vertebrae towards one another. The spine is designed to bear load in this direction as seen when the individual is standing upright and the force of the trunk is compressing the spine into the hips.

However as with all biological systems there is a limit to force that can be tolerated before injury occurs. The National Institute of Occupational Safety and Health (NIOSH) has determined that compressive forces above 3400N, this is equivalent to 763lb of force, show an increased risk of injury to the individual. That is to say that compressive forces below 3400N is unlikely to cause injury in approximately 75% of the population. This force value refers to the internal forces generated within the spine. These forces are generated by a combination of the external load and the load generated by muscles pulling on the body. Forces above 6400N (1437lb) have been seen to cause injury in approximately 75% of the population.

Injuries due to compressive force are usually very difficult to detect, and are usually beyond repair when they are finally diagnosed. Compressive force will act directly on the inter-vertebral disc cause the fluid on the inside of the disc to bulge outward, eventually penetrating the outer layer. Disc herniation is the final stage for compressive force injuries. This is known as 'slipping a disc'. With a high enough force the vertebral body itself can fracture.

#### **Shear Force**

Where compressive force is the movement of vertebrae towards one another, shear force is the movement of vertebrae laterally with respect to one another. The spine is not designed to withstand this direct of loading. Therefore shear forces are much more damaging at lower levels of force. A recent study suggests that rates of injury rise drastically beyond 500N of Joint Reaction Shear and 1000N of Bone on Bone Shear.

When shear forces cause injury to the spine, tearing of the inter-vertebral disc from the vertebral body occurs. The vertebral body is designed to prevent shearing of the spine, but with sufficient force the vertebrae will fracture. The supporting ligaments and muscles around the spine are also susceptible to damage from shear force. The extent of damage will vary with duration and peak force values that occur. So larger forces and greater lengths of time at these elevated forces will generate more severe injuries.

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### **Risk Factors**

It should be noted that there is no such thing as a 'safe' amount of force. Injury is a combination of a number of factors including posture, health, fatigue and gender etc. Any amount of force is capable of causing an injury if the conditions are correct.

PowerMate is designed to limit the damaging forces on the body. There are three main risk factors that will determine the potential for an activity to cause injury.

The first is force, where force is defined as the peak value of force that the body is subjected to. Force will damage tissue when the demand exceeds the tolerance, this is analogous to stretching a rubber band until it snaps.

Posture is the second risk factor to consider when evaluating potential for injury. Posture will define the length and position of tissue. Tissue tolerance will be lower when the tissue length approaches its maximum. Thus a ligament that is stretched to its limit is weaker than one with a lot of stretch reserve. Posture can also result in tissue being forced over sharp or rough underlying structures.

The third risk factor is repetition. Repetitive action can lower tissue tolerance by fatiguing the supporting structures. So a tired muscle is more likely to sustain an injury than a well rested one.

Secondary risk factors include duration and rest. Rest will determine the amount of recovery time a tissue has with the understanding that a fatigued tissue is more susceptible to injury.

### **PowerMate Advantage**

One advantage that PowerMate has over conventional methods is the ease with which a load can be manipulated. PowerMate does not force the body to accommodate any extreme postures. Use of PowerMate requires the operator to bend at the waist, nothing more. In comparison conventional methods require twisting and bending in addition to large force requirements. PowerMate maintains the balance of the

load freeing the operator to concentrate on proper operation and safe delivery of product.

### **Methodology**

Evaluation of PowerMate powered stairclimber was performed using biomechanical analysis and the NIOSH lifting equation.

Biomechanical analysis involves evaluating the forces that result at the fourth and fifth lumbar vertebrae due to the forces in the hand. The forces at the L4/L5 joint will then be compared to the safe limits as suggested by NIOSH and other studies. The NIOSH lifting equation was developed as a method of evaluating the safe limit for a vertical lift, given load dimensions, starting and finishing height.

### **Overview**

Operation of PowerMate powered stairclimber to bring a load up stairs involves leveraging the load over the wheel-axle.

There are two components to this leveraging. The first is pushing down on the handles to allow the load to clear the stair (PUSH), and the second is raising the handles to allow the wheels to clear the step on the way up a flight of stairs (PULL).

Peak force values were obtained using a Chatillon Force Transducer. The test load used had dimensions of 52"/102"/48" and was an empty box made of 1/4" steel. Stair height measured 0.21M. The test load was estimated at 80kg. (176lb). Measurements were made in the saggital plane (side-view), simulating movements required for operation.

### **Break-back**

Prior to moving a load up the stairs the load must be fixed onto the unit. This requires the operator to position the load over the wheel axle of the machine. On a conventional hand truck this is done by placing one foot on the axle and leveraging the load into a moveable position otherwise known as breaking back the load.

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PowerMate has the capacity to allow this leveraging to take place with much less force. The wheels are powered up slightly allowing the load to be leveraged back on the heel plate of the hand-truck eliminating the resistance of the wheels. Once the load is tipped back it comes to rest again upon the wheels in a balanced position.

Each model was tested for the force required to break-back the load with and without PowerMate to assist. The conventional hand truck was also tested for the force required to position the load. PowerMate Pogo was also tested for the force required to perform a tail-lift into a truck.

### Conclusion

#### **Safety**

The PowerMate range of powered stairclimbers is an ergonomically friendly, well-designed system. Conventional methods of moving loads up and down stairs have been shown to be difficult and unsafe.

Using the test load, which was well beneath the operating limit of all the PowerMate models tested, was not difficult to manoeuvre on a flight of stairs or on a flat surface. The load can be positioned to the comfort of the operator. This would indicate that PowerMate is applicable to a wide range of the population, regardless of the height or strength of the operator.

Control of movement is integral to safe work practices. The powered stairclimber allows the load to be manipulated with relative ease, and if necessary, to even stop the load part of the way up or down a flight of stairs. Conventional methods of bringing a load up stairs do not have this safety feature.

This is especially the case with heavy or awkward loads. Trying to bring a load back under control will expose the operator to large peak forces. It is these peak forces which exceed the tissues tolerance limit that will cause acute injuries i.e. fractures or sprains. Thus the ability of PowerMate to prevent loads from getting out of control is a definite advantage. The conventional hand truck places the operator at a great risk of injury.

Using PowerMate, the compressive forces are at least half of that of the conventional hand truck. However, the real safety benefit is in the reduction of shear forces. As mentioned before, shear forces occur in a direction that the spine is not designed to deal with. Shear forces are almost ten times greater when using a conventional hand truck compared to doing the same movement using a PowerMate model. The conventional method was actually unsafe enough for the ergonomist conducting the trial to limit the number of trials performed due to risk of injury.

Breaking back the load utilizing PowerMate reduces the forces on the body by half. This reduces the fatigue that would be endured by the operator who has to frequently start and stop moving a load. In fact once the load is in a moving position, PowerMate is capable of keeping it in the ready position, unlike the conventional hand truck that required breaking the load back for every start.

#### **Labour Saving**

Conventional methods of load delivery have hitherto required a team of workers. This team would be responsible for seeing that the load is delivered safely and without damage to property. PowerMate allows most loads to be handled safely and comfortably by one person.

Under conventional circumstances, the workers would need to be chosen from a small percentage of the population. This population would need to be capable of moving heavy loads, large men are typically chosen as this population. PowerMate allows a wider range of the population to safely manipulate heavy loads.

Using a conventional hand truck, it is necessary to maintain a lifting force when walking along a flat surface, this is to keep the handles of the hand truck off the ground. Both PowerMate models examined have the ability to properly balance the load over the axle to reduce the amount of operator effort required when walking, thus further reducing operator fatigue.

Both PowerMate L1 and PowerMate Pogo also have the capability to allow for the load to be stopped and left in the walking position. This is accomplished by

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using the motor to position the load in a tilted form either by moving the wheels or extending the leg. The load can then be left for a duration while the operator is free to perform other actions i.e. opening a door.

Similarly PowerMate is also capable of positioning the load in a stationary position on a flight of stairs and having it remain in place. This again allows the operator to leave the load to perform another action. An added bonus of being able to leave the load on the stairs is that should the operator feel that they may require assistance to continue, there is the opportunity to stop the load where it is and seek help. This allows the operator to avoid potentially injurious situations.

Conventional hand-trucks do not have this benefit, should the operator find themselves in a dangerous position half-way up or down a flight of stairs there is little option other than to try to safely complete the flight. This does not allow for any safety margin.

### **Energy Reduction**

PowerMate is designed to reduce the amount of energy required from the operator. This energy reduction allows the operator to work more comfortably and at a greatly lowered risk of fatigue (fatigue being previously identified as a risk factor for injury).

PowerMate is also capable of functioning as a tail-lift, which operates by raising the load vertically. A tail-lift operation is performed exactly the same way as stairclimbing. That is to say that the wheels are first raised into the truck and then the load is powered up to the truck bed. Comparing the Pogo to the alternative of two workers dead lifting the load, the Pogo will require forces nearly identical to break back the load. However, the conventional dead lift has forces on the spine that are nearly four times greater.

### **Features**

PowerMate powered stairclimbers are also available with various features that increase the safety and efficiency of its operation. Brakes are an optional accessory which are available on most models. The brakes, either hand or foot actuated, serve to immobilise the wheels against rolling while the load is

being shifted. This further reduces operator effort because it eliminates the need for the stabilising force to come from the operator. There are also different toe-plates available, which would allow for the load to be better stabilised on the hand truck. The toe plates serve to keep the load balanced and secure. PowerMate powered stairclimbers are also designed with non-slip heavy rubber guards for traction during operation, thus eliminating stabilising effort that would otherwise be required from the operator. The rubber guards also provide protection on stair and floor tile surfaces that could otherwise be damaged.

### **Closing**

The PowerMate range of powered stairclimbers is a much safer alternative to conventional hand trucks and dead lifts. The risk of injury is greatly reduced when properly operated.

Shear forces, which are considered particularly damaging to the spine are reduced by at least ten times. Using conventional methods will subject the body to very damaging forces which exceed NIOSH limits by almost two times. It is these reductions in forces that allow the operator to expend less energy to perform their tasks, and with a greatly reduced risk of fatigue. All of these things culminate in a safer load delivery for the operator.

Becoming familiar with PowerMate powered stairclimbers is not difficult, allowing for PowerMate to be rapidly integrated into any working environment. Using PowerMate does not place the body at any increased risk of injury, as noted in the data tables, all forces are within safe operating limits.

### **Acknowledgements**

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