Push-pull forces of wheeled equipment on selected carpets

A report for

Interface Australia

Dohrmann Consulting
Consulting engineers and ergonomists
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Contents

Executive summary

The consultants (engineers and ergonomists) were requested to provide an independent ergonomics assessment of the push-pull efforts required to move typical wheeled hospital equipment over Interface carpet tiles.

The report provides evidence of the effects of different types of floor coverings on the forces required to move various types of wheeled equipment commonly used in health and aged care workplaces. The report is intended to inform managers and others involved in making decisions about the choice of carpets in these settings, thereby assisting in ensuring that their legal obligations for staff safety are met and that the people whose work includes the movement of equipment across carpet will not be exposed to undue risk.

Dohrmann Consulting, previously Mark Dohrmann and Partners Pty Ltd, has now completed three studies of carpets and their effects on pushing and pulling wheeled equipment (August 2010, March 2014 and November 2016). The first and second studies were across 47 carpets. Each of these rounds of tests used six items of wheeled equipment commonly used in health and aged care settings - a bed, a wheelchair, a mobile hoist, a walker and a meals trolley.

In order to further improve accuracy and consistency within the rolling resistance measurements, for the latest round of testing ("Study 3") a standardised test cart was developed. It was a sled fitted with the most common hospital bed/trolley castors, weighted to mimic the previous bed and trolley loads. The test cart was calibrated against the two previous rounds of testing by re-testing earlier carpet samples with the new test cart. This readily enabled the results of all three rounds of tests to be consolidated and compared. The standardised test cart now reduces the variables which can impact the applicability of the results e.g. different beds, worn castors, varying loads.

While there is no current national standardised method for testing the push-pull forces necessary to move wheeled equipment over floor coverings, this apparatus establishes a reliable and objective benchmark for measuring and assessing safe pushing and pulling limits.

In Study Three, the five items of equipment previously tested were replaced with the custom-built standardised test cart. Data obtained with the cart in Study Three was converted into data for each type of wheeled equipment, using the calibrating ratios obtained by retesting previous carpet samples with the test cart.

In each case, the tests first examined initial push and pull force, with the wheels both aligned with the intended direction of movement. The tests were repeated with the castors misaligned, and forces measured for both sustained pushing and pulling.

The results show the forces measured across each carpet surface tested.

General outcomes

Moving a bed consistently required the highest force. It should be noted that many hospitals use powered tuggers for moving beds, or require two workers to move beds with patients in them.

The new Cushion-back carpet tested in Study 3 did not consistently require more force than the Glasbac (the Cushion-back is softer). This suggests that the cushion-back does not allow the castor to 'sink' into the surface to the same extent as previously. Additionally, the character of the carpet pile likely has a stronger direct relationship with the rolling resistance experienced by the wheeled equipment.

Based on the measurements taken in these studies, all the carpeted surfaces allowed safe push and pull forces for the equipment tested, for infrequent movement over relatively short distances. Some carpets required lower forces and are thus more suitable where frequent movement of wheeled equipment is required.

Important note for consumers

This study examined and compared different types of carpets for different wheeled equipment. It cannot guarantee that a given carpet will be "safe" for all equipment in all circumstances. Rolling resistance is affected not only by carpet type, but also by castor diameter, rim type, rim thickness, castor type and condition; by bearing type; by the gross load; by the distance pushed or pulled; by the height of the handles; by training and experience. These are matters in the customer's control.

Heavier gross weights will likely result in higher forces; however, this is not likely to be a linear correlation. At some point, heavier equipment or smaller castors may require additional risk controls, such as using a powered tugger or requiring two people to work together.

Other factors to consider when choosing floor coverings in various parts of health and aged care facilities include cost (including installation); the cost of maintenance and cleaning; ease of cleaning; infection control issues; incontinence issues; slips, trips and falls (likelihood and consequences); fatigue on feet and legs; noise control; glare control; and aesthetics. For example, aged care facilities are both a person's home as well as a workplace, and the needs and legal requirements of each ought to be fulfilled, as far as possible.

Background

Dohrmann Consulting (an ergonomics and safety consulting firm) was engaged by Interface to undertake an independent ergonomics assessment of a range of carpets.

The aim of the project was to provide scientific evidence which demonstrated the effects of different types of carpet tiles on the forces required to move nominated types of wheeled equipment commonly used in health and aged care workplaces. The report is intended to assist managers and others involved in making decisions about the design of workplaces, in the context of their duty to ensure the health and safety of the people who will work in the facility and who may be required to manoeuvre and move wheeled equipment.

The project comprised a series of tests on various carpets carried out over three studies. In 2010 (Study One), 2014 (Study Two) and in 2016 (Study Three).

This report now sets out the combined results of these assessments. The advice contained herein is based on the independent results and conclusions drawn from these three projects.

Guidance Material

The criteria used to assess whether the relevant forces were safe or not was compliance with the *Tables of Acceptable Forces* published by Snook and Ciriello (1991). This is a well-accepted guide within the occupational health and safety field.

The Snook Tables were used as the prime criterion of acceptability in these tests, because they have been validated against epidemiological injury data. A research report on ergonomic guidelines for manually-handled trolleys in the health industry conducted for the Central Sydney Area Health Service by Lawson and Potiki (1994) analysed a range of research studies, including those of Snook and colleagues, and recommended the following values for pushing/pulling of trolleys, for a mixed male/female workforce:

- 17 kg to 21 kg for initial force
- 6 kg to 12 kg for sustained force.

The values at the lower end of the range are recommended as optimum limits, and in particular are applicable to high frequency and longer duration tasks. The values at the higher end of the range are maximum limits, for infrequent, short duration tasks.

The Snook Tables specify separate maximum acceptable forces for lifting, lowering, pushing, pulling and carrying. There are separate tables of pushing/pulling for men and for women. To assist in ensuring the workplace is safe so far as reasonably practicable, we have used the relevant tables for women. The corresponding maximum acceptable forces for men are generally higher than those for women, so if a task is found acceptable for women, it will also be acceptable for men (in force terms). For example, the Snook Tables advise that a sustained force of 12 kg is acceptable to 75% of the female working population for a pull distance of 30.5 metres with the hands at a height of 1.35 m, once every eight hours, or for a pull distance of 7.6 metres done every five minutes.

Method

Wheeled equipment tested

Study One testing (2010) was carried out in an open area at an aged care facility, using five items of equipment currently in use at that facility, plus a wheeled suitcase and a hotel porter's trolley.

Study Two testing was carried out in an open area at the Interface offices in South Melbourne, using five items of equipment currently in use at most health facilities. Descriptions of the items of equipment used in each study are set out in Appendix F.

Study One and Two equipment was borrowed for the period of the testing, and returned afterwards. The equipment was not modified in any way for the testing. The equipment was visually assessed and no apparent defects likely to affect push or pull forces were found. Wheelchair tyres were inflated to the recommended pressure of 4.5 bar. In order to simulate operational conditions, the patient transfer equipment was loaded with a total of 70 kg. The other items were loaded to the weights set out in Appendix F.

Study Three testing was carried out in the same area as Study Two at the Interface offices in South Melbourne, using the calibrated standardised test cart. The castors were selected to simulate worst case scenario of castors types commonly used for wheeled equipment within a hospital setting. Details of the standardised test cart are in Appendix D.

Floor coverings tested

Study One consisted of eighteen samples of floor covering, Study Two of twenty-nine samples and Study Three forty-five.

All carpet tiles were provided and installed by Interface, using a direct-stick installation method in Study One and 'TacTiles' in Studies Two and Three. All carpets were installed on a flat concrete floor.

In Study One and Two, all floor coverings were tested in two opposite directions, to control for any variation in floor slope or directional resistance of the carpet. In Study Three the floor was confirmed as level, and directional resistance of the carpets was tested, as appropriate. If the carpet was laid in a directional or "Ashlar" method, the test was completed in two opposing directions. If "Quarter Turn" or "Random" installation methods were used, the testing trolley was positioned across differently-oriented tiles to take account of any variations in directional resistance.

Three types of backing material were tested across the three studies. The Glasbac is a relatively firm backing material and its composition has not changed across the three studies. The Cushion-back in Study one was an SBR Foam cushion and the Cushion-back from Study Three was Interface's new Recycled PET Cushion-back. These are referenced appropriately throughout the report.

Details of all the floor coverings were provided by Interface and are set out in Table 1 below.

Details of floor coverings tested

Carpet	Backing	Installation method
A Cut Above	GlasBac	Random
A Cut Above	Recycled PET Cushion	Random
Alliteration	Glasbac	Directional
Asana	Glasbac	Random
Asana	Recycled PET Cushion	Random
Bertola	Glasbac	Directional
Bioscape	Glasbac	Directional
Bioscapes	GlasBac	Quarter Turn
Bioscapes	Recycled PET Cushion	Quarter Turn
Broadloom wool	Hessian	Directional
Continuum	Glasbac	Directional
Continuum	SBR Foam Cushion	Directional
Cubic Colours	Glasbac	Directional
Cubic Colours	SBR Foam Cushion	Directional
Duo	GlasBac	Ashlar
Duo	Recycled PET Cushion	Ashlar
Equilbrium II	Glasbac	Directional
Equilibrium	GlasBac	Quarter Turn
Equilibrium	Recycled PET Cushion	Quarter Turn
Fast forward	Glasbac	Directional
Fast forward	SBR Foam Cushion	Directional
Flow	Glasbac	Directional
Freestyle	Glasbac	Directional
Fusion	Glasbac	Quarter turn
Good Natured	GlasBac	Ashlar
Head Over Heels	Recycled PET Cushion	Random
Hip Over History	GlasBac	Random
Hip Over History	Recycled PET Cushion	Random
Llano	Glasbac	Directional
Llano	Glasbac	Quarter turn
Llano	GlasBac	Directional
Longitude	Glasbac	Quarter Turn
Muse	Glasbac	Ashlar
Muse	GlasBac	Ashlar
Muse	Recycled PET Cushion	Quarter Turn
Net Effects B601	Glasbac	Random
Net Effects B601	Recycled PET Cushion	Random
Net Effects B603	Glasbac	Random
Net Effects B603	Recycled PET Cushion	Random
Nubian	Glasbac	Quarter turn
On Line	GlasBac	Ashlar
On Line	Recycled PET Cushion	Ashlar
Outlook	Glasbac	Directional
Outlook	SBR Foam Cushion	Directional
Platform	Glasbac	Directional
Portmanteau PM01	GlasBac	Ashlar
Portmanteau PM049	GlasBac	Ashlar
Prairie Grass	Glasbac	Directional

Carpet	Backing	Installation method
Prairie Grass	Glasbac	Quarter turn
Prairie Grass	GlasBac	Directional
Raw	Glasbac	Random
RMS 101	GlasBac	Quarter Turn
RMS 102	GlasBac	Quarter Turn
RMS 103	GlasBac	Quarter Turn
RMS 606	GlasBac	Quarter Turn
RMS 607	GlasBac	Quarter Turn
RMS 607	Recycled PET Cushion	Quarter Turn
RMS 608	GlasBac	Quarter Turn
Rococo	Glasbac	Directional
San Rocco	Glasbac	Directional
Solace	Glasbac	Directional
Solid Ground UR303	Recycled PET Cushion	Ashlar
Stitched Up	Glasbac	Directional
Striation	Glasbac	Directional
Suits you	SBR Foam Cushion	Directional
Syncopation	Recycled PET Cushion	Quarter Turn
Syncopations	Glasbac	Directional
Syncopations	SBR Foam Cushion	Directional
Tempest	Glasbac	Directional
The Loop	Glasbac	Directional
The Loop	SBR Foam Cushion	Directional
Trio	GlasBac	Ashlar
Trio	Recycled PET Cushion	Ashlar
Urban retreat 101	Glasbac	Quarter turn
Urban retreat 101	Glasbac	Random
Urban retreat 201	Glasbac	Quarter turn
Urban retreat 202	Glasbac	Directional
Urban retreat 203	Glasbac	Quarter turn
Urban retreat 302	Glasbac	Quarter turn
Urban retreat 303	Glasbac	Directional
Vermont	Glasbac	Directional
Walk the plank	Glasbac	Directional
WE 151 Whole Earth	GlasBac	Ashlar
WE 151 Whole Earth	Recycled PET Cushion	Ashlar
World Woven 890	GlasBac	Ashlar
World Woven 890	Recycled PET Cushion	Ashlar
World Woven 895	GlasBac	Ashlar
World Woven 895	Recycled PET Cushion	Ashlar
Yin Yang	Glasbac	Directional
Yin Yang	SBR Foam Cushion	Directional

Table 1

Force measurements

Forces were measured using a hand-held calibrated analogue force gauge, Model NK-500 (Figure 1). The unit was set to read the peak force during each measurement. Forces are presented here as kilograms (or kg – a weight) rather than Newtons (a force) because although it is a weight, not a force, the kg unit is likely to be more familiar to most readers.

Figure 1

Measurements were made of the horizontal force required to pull each item of equipment from rest, and then continuously. Equipment was steered in a straight line during each test. Push forces were assumed to be identical to pull forces for equipment with wheels on normal pedestrian surfaces, so push forces were not separately measured. This assumption would not be valid in the case of sliding of non-wheeled equipment, which can tend to "nose dive" into the floor covering when pushed.

Each floor covering was laid in turn, and all the tests were done on each surface before moving on to the next surface. As noted, each item of equipment was tested for initial force – to get the item moving, and for the sustained force to keep it moving. Initial forces were measured with the wheels aligned in the direction of intended travel, then with the wheels set at right angles to the direction of travel. Study Three positioned the front wheels at an angle of 135 degrees from the direction of travel, and the back wheels at an angle of 45 degrees (Figure 2). This configuration maximised the amount of rotation a non-aligned castor had to make from rest, to better test rotational resistance of the samples. Examination of "non-aligned" force data across the three studies did not reveal any significant differences in force.

Figure 2

In Studies One and Two, each test was repeated five times and the measurement recorded. The highest and lowest values in each set of five readings were discarded to avoid an outlying value affecting the result, then the average of the three remaining readings was calculated. The final reading was the average of the three middle values in both directions.

In Study Three each test was repeated three to five times, depending on the consistency of the result. Outlying values were ignored and the average across the remaining readings calculated.

The measurements were entered directly onto a spreadsheet for processing.

The sustained forces result from two main factors: internal resistance of the wheels of the device being moved, and resistance between the wheels and the floor surface. In setting safe acceptance levels, the forces referenced in the Snook Tables (described above in *Guidance Material*) have been those for *pushing* and *pulling.* Generally, the equipment is more likely to be pushed than pulled in a real environment. Safe pushing limits are also referenced to gender; to the percentage of the target group who will be comfortable at the upper force limit; to the height of the hands when pushing; to the frequency of the task; to the distance pushed; and to the distinction between the initial “get-it-moving” force and the sustained force needed to keep it moving at a steady speed.

Results

Sustained push/pull force results

The sustained push forces for each item of equipment, averaged over all the floor coverings, are shown in Figure 3. Clearly the bed was hardest to push. The other equipment was easier to push because of either larger diameter wheels and/or a lighter load. The sustained push forces for the walker, food trolley and wheelchair were low.

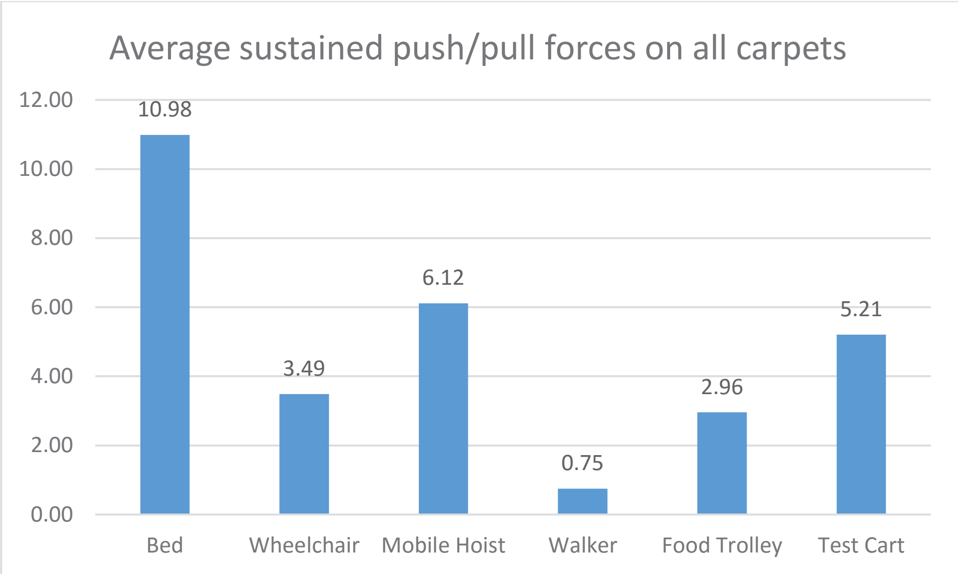


Figure 3

The average sustained pushing forces were below 11 kg on all of the floor coverings. This is within the range recommended by Lawson and Potiki (1994) of 6 to 12 kg for sustained force.

Examination of the Snook tables indicates that a sustained force of 11 kg is acceptable to 75% of the female working population for a distance of 30.5 metres once per minute, or for a distance of 7.6 metres once every 15 seconds, or for a 61 metre push once per 5 minutes.

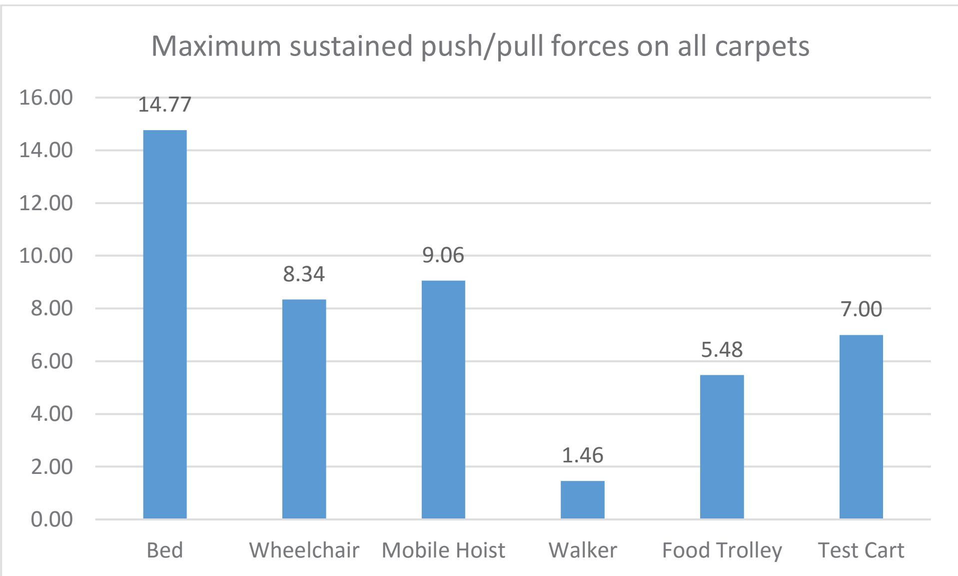


Figure 4

The maximum force measured for pushing a bed is over the maximum acceptable force of 12 kg. It is noted that must hospital beds are moved with two people or mechanical assistance. All other equipment, across all carpets was measured with a sustained force of 9 kilograms or less.

The sustained bed pulling forces for the majority of the carpets were below 12 kg. This is within the range recommended by Lawson and Potiki (1994) of 6 kg to 12 kg for sustained force. There were twenty-three carpets that exceeded 12 kg for the sustained pull force, by a small margin.

These were:

Carpet	Backing	Installation Method
Bioscapes	GlasBac	Quarter Turn
RMS 607	Recycled PET Cushion	Quarter Turn
A Cut Above	Recycled PET Cushion	Random
Syncopation	Recycled PET Cushion	Quarter Turn
Walk the plank	Glasbac	Directional
RMS 607	GlasBac	Quarter Turn
Duo	Recycled PET Cushion	Ashlar
Vermont	Glasbac	Directional
Asana	Recycled PET Cushion	Random
Hip Over History	Recycled PET Cushion	Random
San Rocco	Glasbac	Directional
Urban retreat 101	Glasbac	Quarter turn
Net Effects B601	Glasbac	Random
RMS 103	GlasBac	Quarter Turn
Urban retreat 201	Glasbac	Quarter turn
Urban retreat 203	Glasbac	Quarter turn
Head Over Heels	Recycled PET Cushion	Random
Net Effects B601	Recycled PET Cushion	Random
RMS 608	GlasBac	Quarter Turn
Urban retreat 303	Glasbac	Directional
World Woven 890	GlasBac	Ashlar
Tempest	Glasbac	Directional
Equilibrium	Recycled PET Cushion	Quarter Turn

Table 2

Examination of the Snook Tables for handle heights between 90 cm and 135 cm for the bed indicates the following:

- *A sustained push* force of 12 kg is acceptable to 75% of the female working population for a distance of 30.5 metres every eight hours, or for a distance of 7.6 metres every 5 minutes.

- *A sustained pull* force of 12 kg is acceptable to 75% of the female working population for a distance of 30.5 metres every eight hours, or for a distance of 7.6 metres every minute.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm for the mobile hoist and wheelchair indicates that -

- *A sustained push* force of 8 - 9 kg is acceptable to 75% of the female working population for a distance of 45.7 metres every eight hours, or for a distance of 15.2 metres once every minute.

- *A sustained pull* force[1] of 8 - 9 kg is acceptable to 75% of the female working population for a distance of 45.7 metres every two minutes, or for a distance of 15.2 metres once every 35 seconds.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm for the food trolley indicates that -

- *A sustained push* force of 5.5 kg is acceptable to 75% of the female working population for a distance of 61 metres every 2 minutes, or for a distance of 15.2 metres once every 25 seconds. This covers most work situations that are likely to arise.

- *A sustained pull* force of 5.5 kg is acceptable to 75% of the female working population for a distance of 61 metres every 2 minutes, or for a distance of 15.2 metres every 25 seconds. This covers most work situations that are likely to arise.

Examination of the Snook Tables for handle heights between 58 cm and 89 cm for the standardised test cart indicates that -

- *A sustained push* force of 7 kg is acceptable to 75% of the female working population for a distance of 61 metres every 2 minutes, or for a distance of 15.2 metres once every 25 seconds. This covers most work situations that are likely to arise.

- *A sustained pull* force of 7 kg for is acceptable to 75% of the female working population for a distance of 61 metres every 2 minutes, or for a distance of 15.2 metres once every 25 seconds. This covers most work situations that are likely to arise.

1 A pull force is unlikely to performed for a wheelchair.

The Standardised test cart results shown in Figure 5 and Figure 6 for sustained push/pull forces were all measured as 7 kg or less. Providing acceptable rolling resistance across the carpet types tested for the generic rolling equipment calibrated and tested.

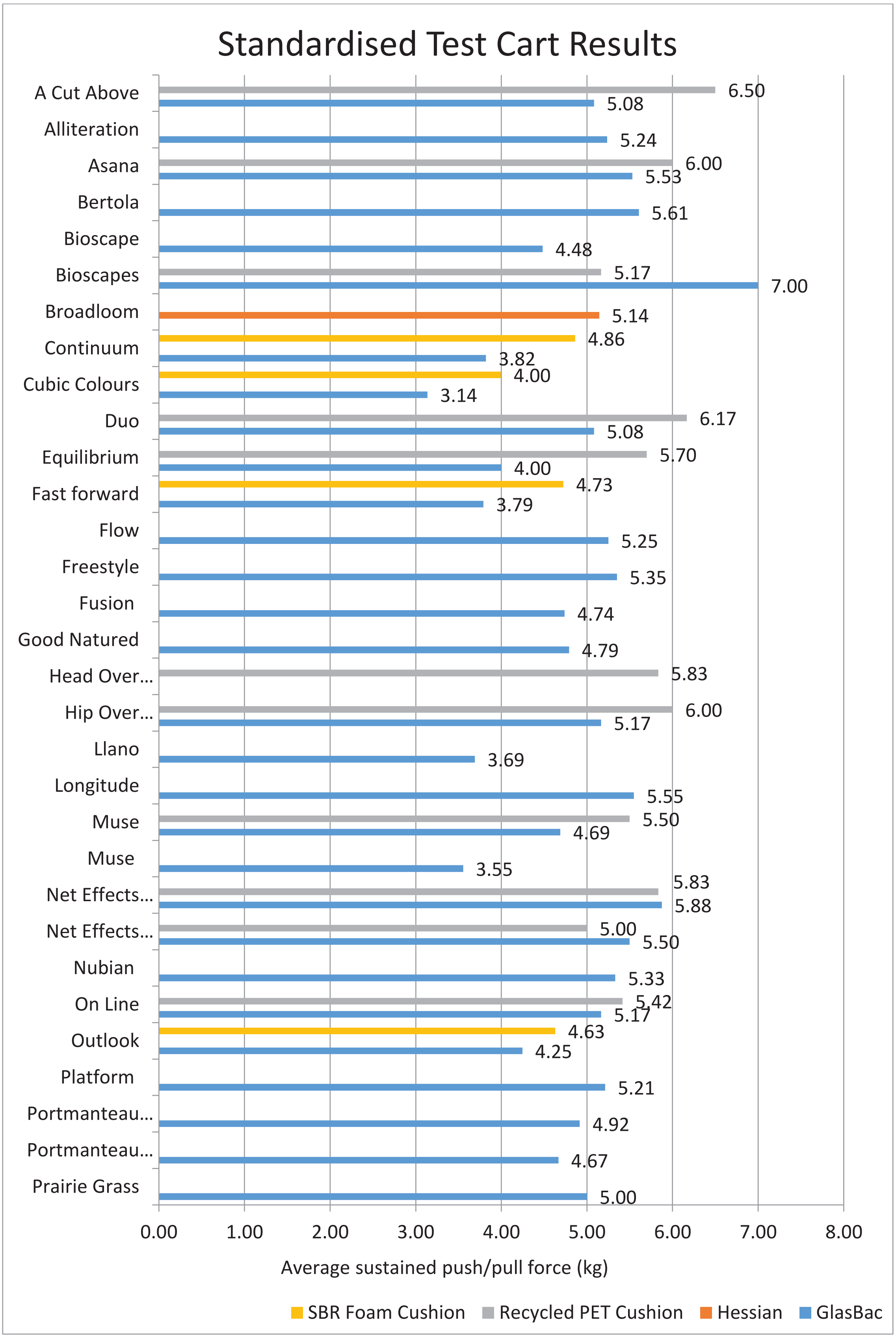
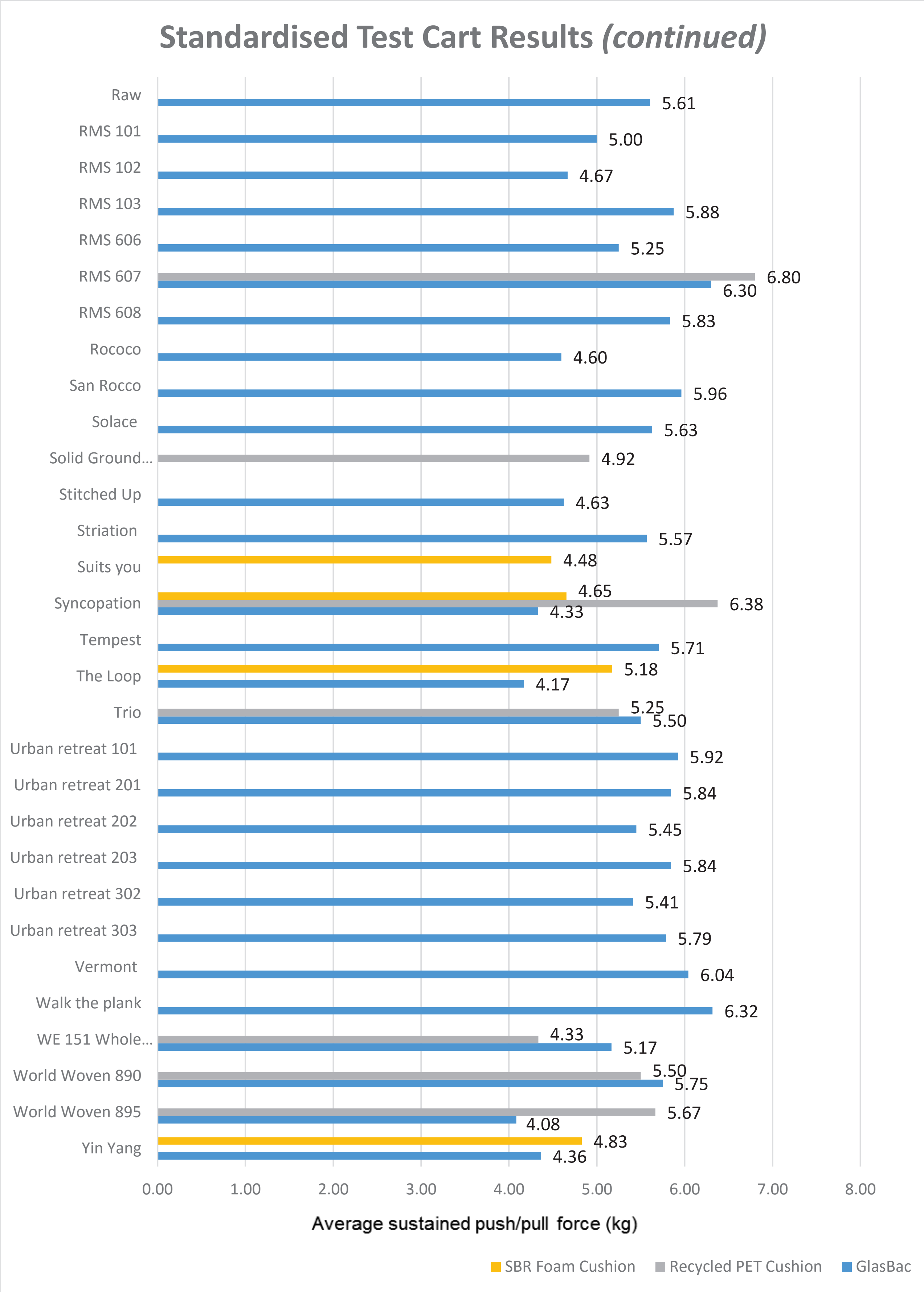


Figure 5



Standardised Test Cart Results (continued)
Raw
5.61
RMS 101
5.00
RMS 102
4.67
RMS 103
5.88
RMS 606
5.25
RMS 607
6.80
6.30
RMS 608
5.83
Rococo
4.60
San Rocco
5.96
Solace
5.63
Solid Ground...
4.92
Stitched Up
4.63
Striation
5.57
Suits you
4.48
Syncopation
4.65
6.38
4.33
Tempest
5.71
The Loop
5.18
4.17
Trio
5.25
5.50
Urban retreat 101
5.92
Urban retreat 201
5.84
Urban retreat 202
5.45
Urban retreat 203
5.84
Urban retreat 302
5.41
Urban retreat 303
5.79
Vermont
6.04
Walk the plank
6.32
WE 151 Whole...
4.33
5.17
World Woven 890
5.50
5.75
World Woven 895
5.67
4.08
Yin Yang
4.83
4.36
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
Average sustained push/pull force (kg)
SBR Foam Cushion
Recycled PET Cushion
GlasBac

Figure 6

Carpet Backing Comparison for sustained push/pull forces

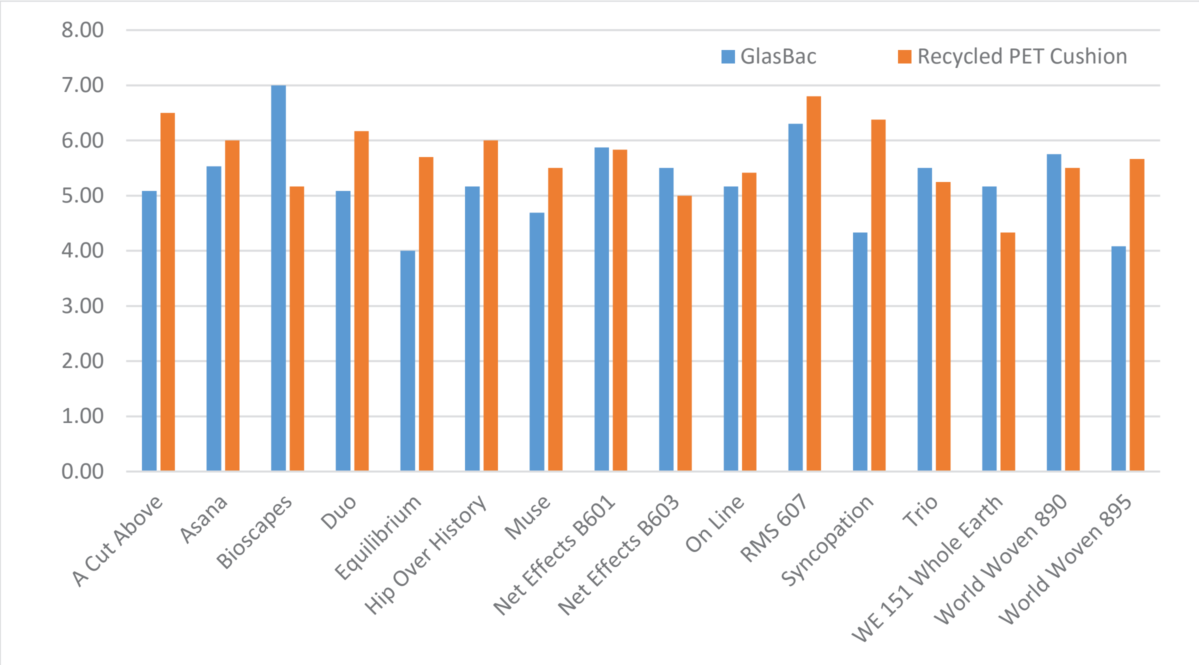


Figure 7

The variation between the *Recycled PET Cushion-back* material and the *GlasBac* is minimal for most carpets tested. The higher sustained forces are not always with the Cushion-back material, suggesting that the backing type does not significantly influence the sustained push/pull forces.

Initial push/pull force results – castors aligned in direction of travel

The initial forces for each item of equipment with wheels initially aligned, averaged over all the floor coverings, are shown in Figure 8. The bed was again hardest to move, followed by the standardised test cart and mobile hoist. The other equipment was again easier to move because of larger diameter wheels and/or a lighter load.

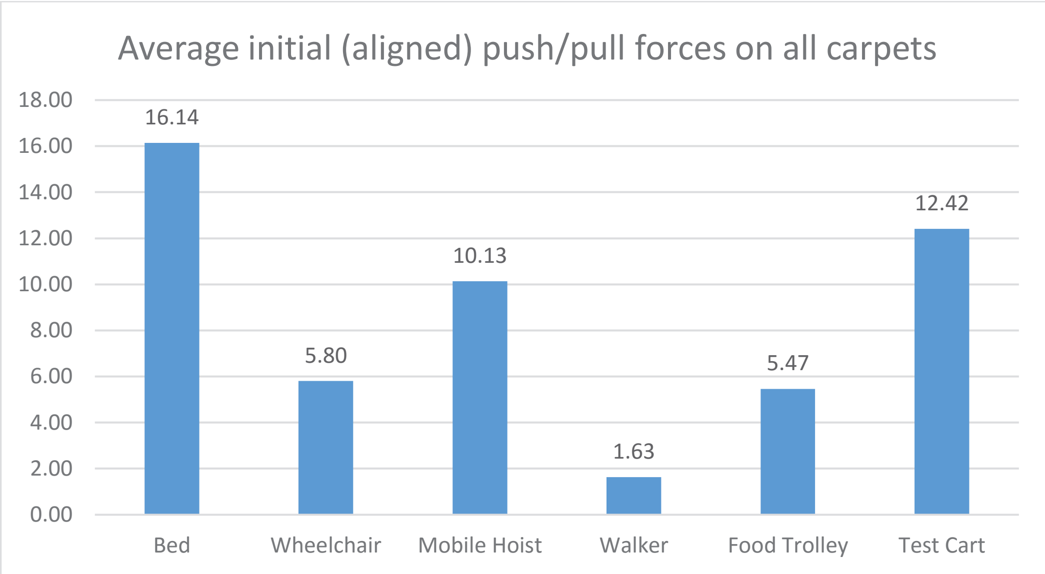


Figure 8

The average initial movement forces were below 17 kg on all of the floor coverings. This is below the range recommend by Lawson and Potiki (1994) of 17 kg to 21 kg for initial force.

Examination of the Snook tables indicates that an initial pushing force of 17 kg is acceptable to 75% of the female working population for a distance 61 metres once per 30 minutes, or for a distance of 45.7 metres once per 5 minutes, or for a distance of 15.2 metres once every 2 minutes. This is likely to cover most hospital and aged care situations.

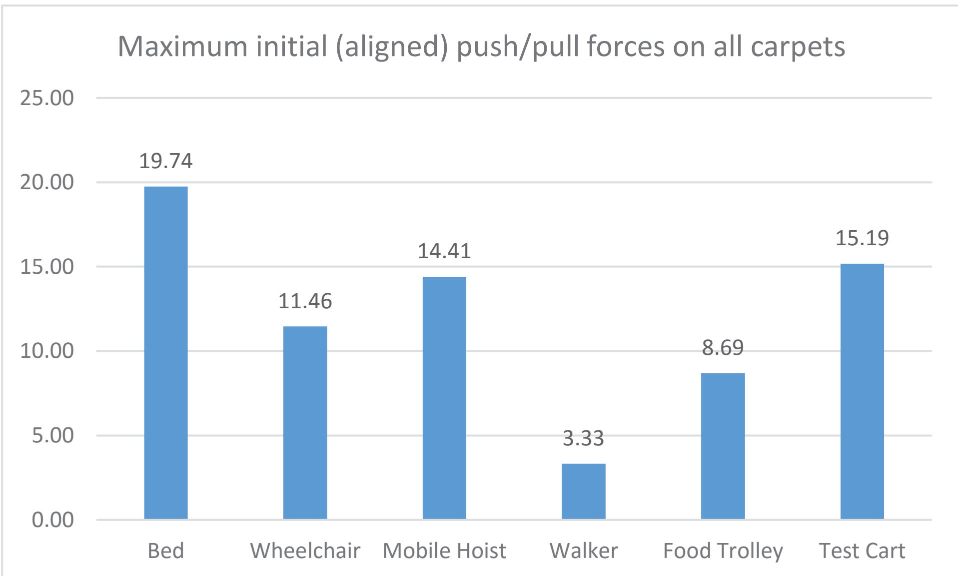


Figure 9

The initial bed pushing forces were 19.74 kg or below on all of the floor coverings. This is within the range recommended by Lawson and Potiki (1994) of 17 to 21 kg for initial force.

Examination of the Snook tables indicates that an initial force of 19 kg is acceptable to 75% of the female working population for a distance 61 metres once every 8 hours, or for a distance of 45.7 metres once every 30 minutes, or for a distance of 15.2 metres once every 5 minutes.

The maximum initial force measured for pulling a mobile hoist with wheels aligned on any of the surfaces was 14.4 kg.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm indicates that -

- an initial push force of 14 kg is within the maximum force acceptable to 75% of the female working population for a distance of 61 metres once every 2 minutes, or for a distance of 45.7 metres once every minute, or for a distance of 2.1 metres every 6 seconds.
- an initial pull force of 14 kg is within the maximum force acceptable to 75% of the female working population for a distance of 61 metres once every 2 minutes, or for a distance of 45.7 metres once every minute, or for a distance of 2.1 metres every 6 seconds.

The maximum initial force measured for pulling the wheelchair, food trolley and walker with wheels aligned were all below 12 kg.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm indicates that -

- an initial push force of 12 kg is within the maximum force acceptable to 75% of the female working population for a distance of 61 metres once every 2 minutes, or for a distance of 45.7 metres once every minute, or for a distance of 2.1 metres every 6 seconds.
- an initial pull force of 12 kg is within the maximum force acceptable to 75% of the female working population for a distance of 61 metres once every 2 minutes, or for a distance of 45.7 metres once every minute, or for a distance of 2.1 metres every 6 seconds.

This covers most work situations that are likely to arise.

The maximum initial force measured for pulling the standardised test cart with wheels aligned was below 16 kg.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm indicates that -

- an initial push force of 16 kg is within the maximum force acceptable to 75% of the female working population for a distance of 61 metres once every 5 minutes, or for a distance of 45.7 metres once every 2 minutes, or for a distance of 2.1 metres every 6 seconds.
- an initial pull force of 16 kg is within the maximum force acceptable to 75% of the female working population for a distance of 61 metres once every 30 minutes, or for a distance of 45.7 metres once 2 minutes, or for a distance of 2.1 metres every 6 seconds.

The Standardised test cart results shown in Figure 10 and Figure 11 for initial (aligned) push/pull forces were all measured as 15.19 kg or less. Providing acceptable initial force across the carpet types tested for the generic rolling equipment calibrated.

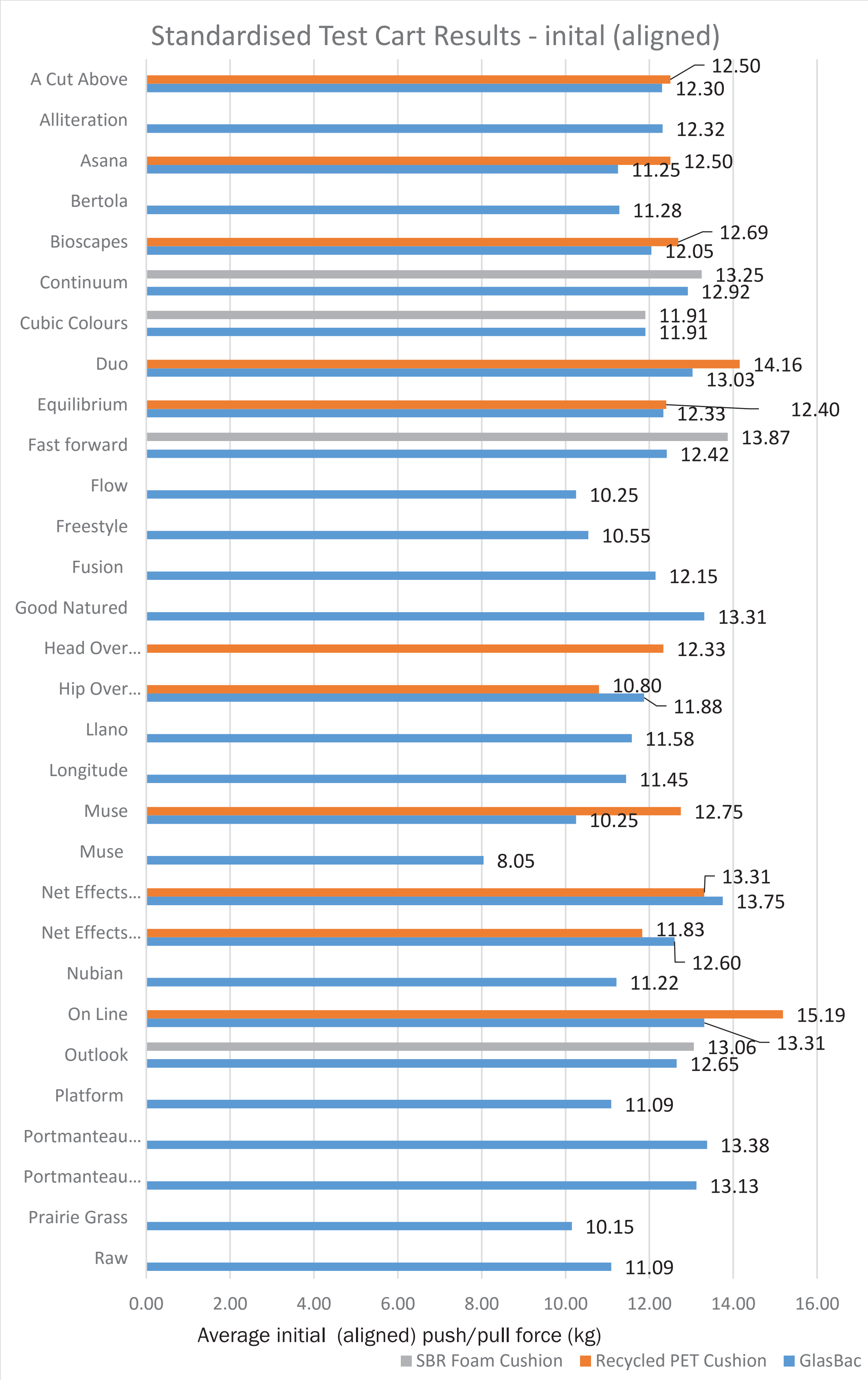


Figure 10

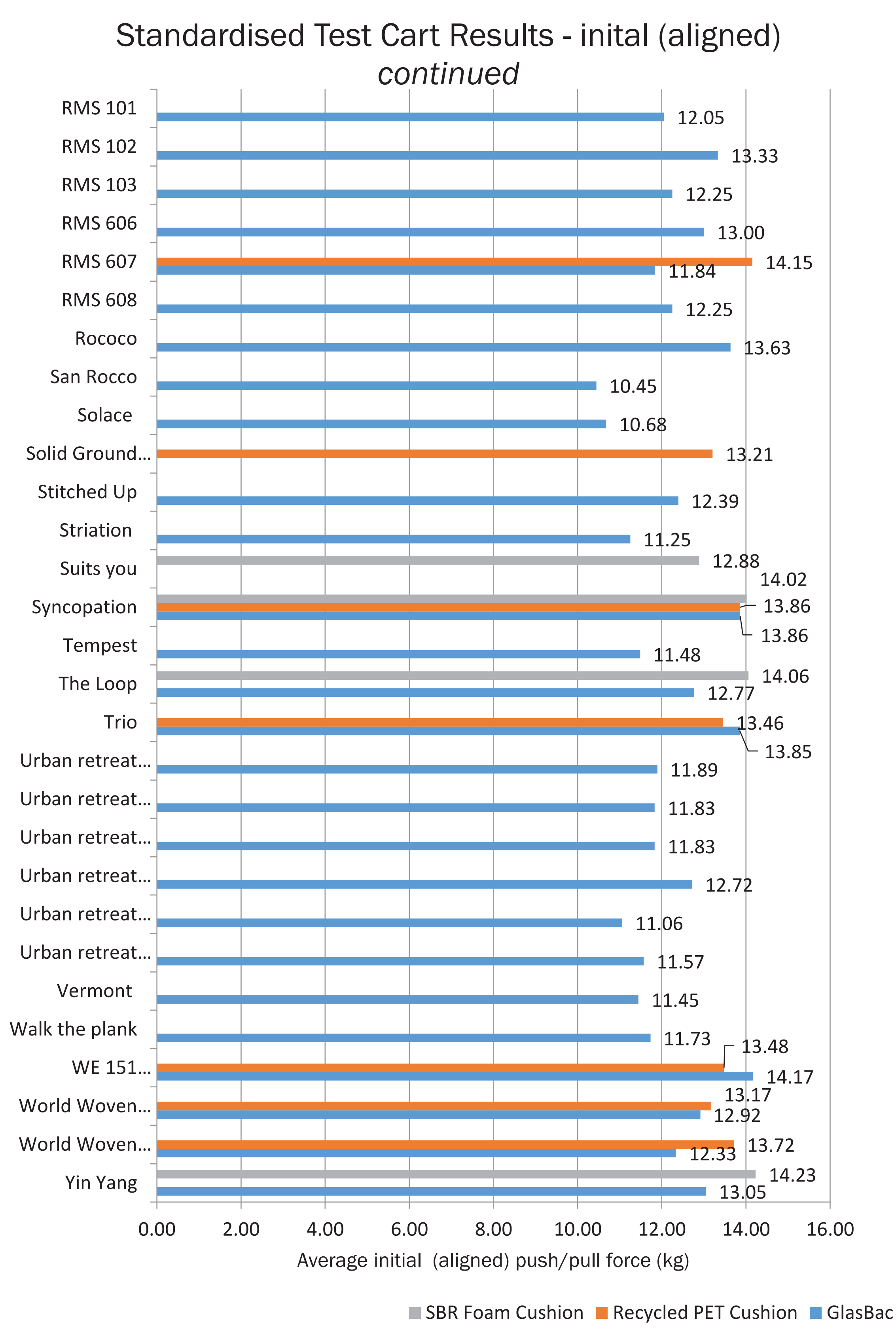

Standardised Test Cart Results - inital (aligned)
continued
RMS 101
12.05
RMS 102
13.33
RMS 103
12.25
RMS 606
13.00
RMS 607
14.15
11.84
RMS 608
12.25
Rococo
13.63
San Rocco
10.45
Solace
10.68
Solid Ground...
13.21
Stitched Up
12.39
Striation
11.25
Suits you
12.88
14.02
Syncopation
13.86
13.86
Tempest
11.48
The Loop
14.06
12.77
Trio
13.46
13.85
Urban retreat...
11.89
Urban retreat...
11.83
Urban retreat...
11.83
Urban retreat...
12.72
Urban retreat...
11.06
Urban retreat...
11.57
Vermont
11.45
Walk the plank
11.73
WE 151...
13.48
14.17
World Woven...
13.17
12.92
World Woven...
13.72
12.33
Yin Yang
14.23
13.05
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Average initial (aligned) push/pull force (kg)
SBR Foam Cushion
Recycled PET Cushion
GlasBac

Figure 11

Carpet Backing Comparison for initial (aligned) push/pull forces

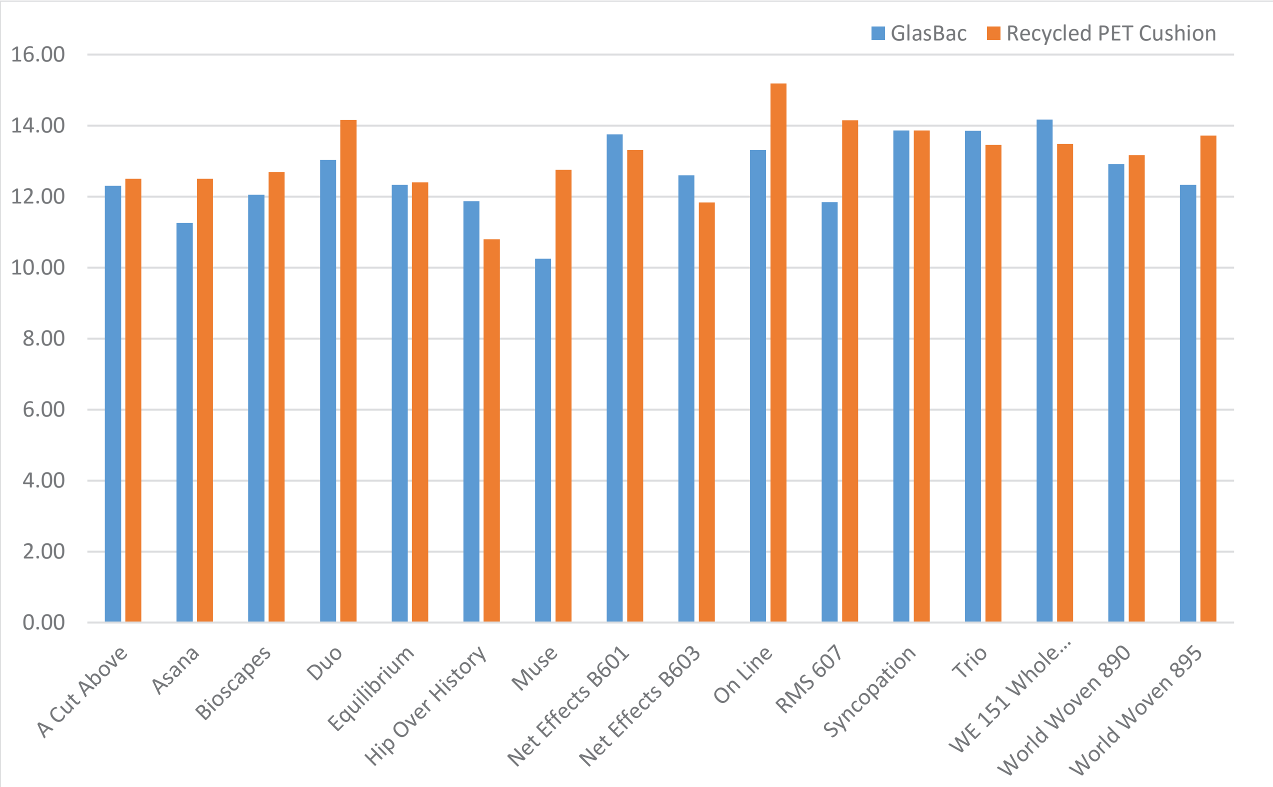


Figure 12

The variation between the *Recycled PET Cushion-back* material and the *GlasBac* is less than 2 kg for most carpets tested. Six of the sixteen carpets tested with both backing materials showed less initial force values for the Cushion-back option. These carpets were Hip over history, Net Effects B601, Net Effects B603, Synocopation, Trio and WE 151 Whole Earth.

The higher initial forces were not always with the Cushion-back material, suggesting the backing type does not significantly influence the initial push/pull forces, with the castors aligned in the direction of travel.

Initial push/pull force results – castors not aligned in direction of travel

The initial forces for each item of equipment with wheels initially not aligned, averaged over all the floor coverings, are shown in Figure 13. The bed was again hardest to move, followed by the standardised test cart and mobile hoist. The other equipment was easier to move because of larger diameter wheels and/or a lighter load.

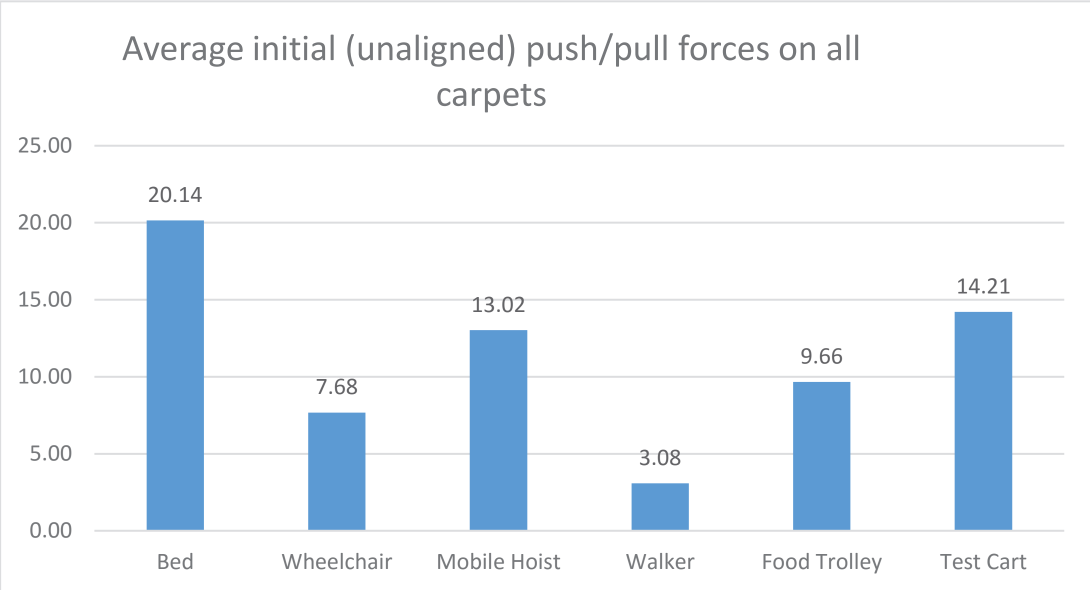


Figure 13

The situation in which the wheels are initially set at right angles to the direction of travel represents the worst-case scenario in pushing equipment with wheels that swivel. During the testing, the wheels were set at right angles – in the case of the bed, the lifter and the food trolley, this meant all four wheels; and in the case of the other equipment only two of the wheels swivelled. The force required showed considerable variability, and the ease depends on the castors as well as the floor covering. These results are a useful indicator of the difficulty of manoeuvring equipment into or out of tight spaces, but are less relevant to the majority of pushing tasks.

The initial bed pushing forces averaged about 20 kg on all of the floor coverings. This is at the upper end of the range recommended by Lawson and Potiki (1994) of 17 to 21 kg for initial force for a female worker working on her own.

Examination of the Snook tables indicates that an initial force of 20 kg is acceptable to 75% of the female working population for a distance of 15.2 m every 30 minutes, or a distance of 7.6 metres once every 2 minutes, or 2.1 metres once every minute. Practically, these are somewhat restricted conditions. In practice, staff should be trained to move the bed in the direction of the wheels first, and then change the direction of the push towards the intended direction of travel once the bed is moving – this avoids the peak forces imposed by pushing at right angles to the wheels when they are stationary. Where practicable, two staff should assist to get the bed moving, after which one staff member may provide the sustained push force, subject to the frequency and distance being acceptable.

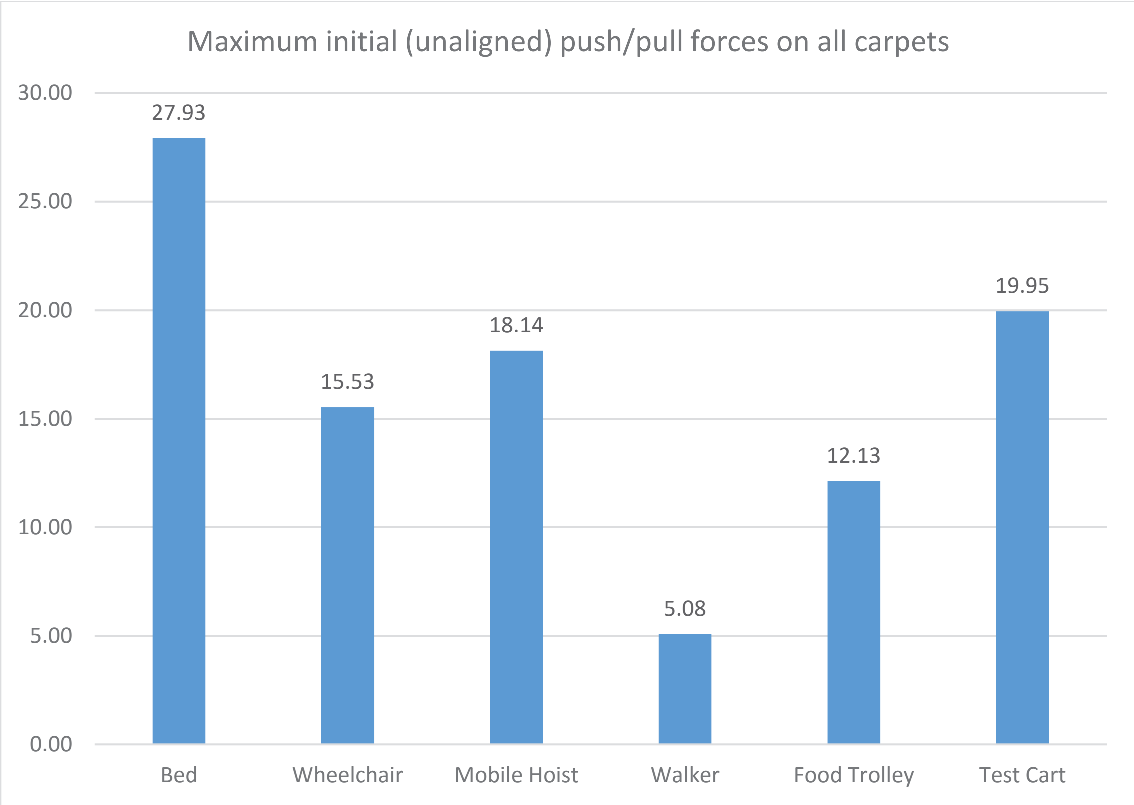


Figure 14

The initial bed pulling forces with the castors not aligned were in the approximate range of 12.5 kg to 28 kg on all the floor coverings tested (the maximum was 27.93 kg). This is above the range recommended by Lawson and Potiki (1994) of 17 kg to 21 kg for initial force for a female worker working on her own. The results in the approximate range from 23 – 28 kg were all from Study One. These results may reflect a different bed used to complete the test in Study One, resulting in higher maximum values.

The Snook Tables for handle heights between 90 cm and 135 cm state that -

- *An initial push* force of 23 kg is acceptable to 75% of the female working population for a distance 7.6 metres every 30 minutes, or for a distance of 2.1 metres every five minutes.

- *An initial pull* force of 23 kg is acceptable to 75% of the female working population for a distance 7.6 metres every eight hours, or for a distance of 2.1 metres every five minutes.

The maximum initial force measured for pulling a mobile hoist with the wheels initially not aligned was 18.14 kg across all the floor coverings. This is less than the bed pulling forces. This is within the range recommended by Lawson and Potiki (1994) of 17 kg to 21 kg for initial force for a female worker on her own.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm indicates that -

- *An initial push* force of 18 kg is acceptable to 75% of the female working population for a distance of 61 metres every eight hours, or for a distance of 45.7 metres every 30 minutes, or for a distance of 2.1 metres every 12 seconds.

- *An initial pull* force of 18 kg is acceptable to 75% of the female working population for a distance of 61 metres every eight hours, or for a distance of 45.7 metres every 30 minutes, or for a distance of 2.1 metres every 12 seconds.

The maximum initial force measured for pulling the wheelchair was 15.53 kg across all the floor coverings. Noteworthy here is that across Study Two and Three the maximum force reduced significantly to 8.6 kg.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm indicates that -

- *An initial pull* force of 15 kg is within the capability of 75% of the female working population for a 61 metre pull every 5 minutes, or for a 7.6 metre pull every 15 seconds, or for a 2.1 metre pull every 6 seconds.

- *An initial push* force of 15 kg is within the capability of 75% of the female working population for a 61 metre pull every 5 minutes, or for a 7.6 metre pull every 15 seconds, or for a 2.1 metre pull every 6 seconds.

The maximum initial force measured for pulling the meal trolley was 12.13 kg across all the floor coverings.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm indicates that -

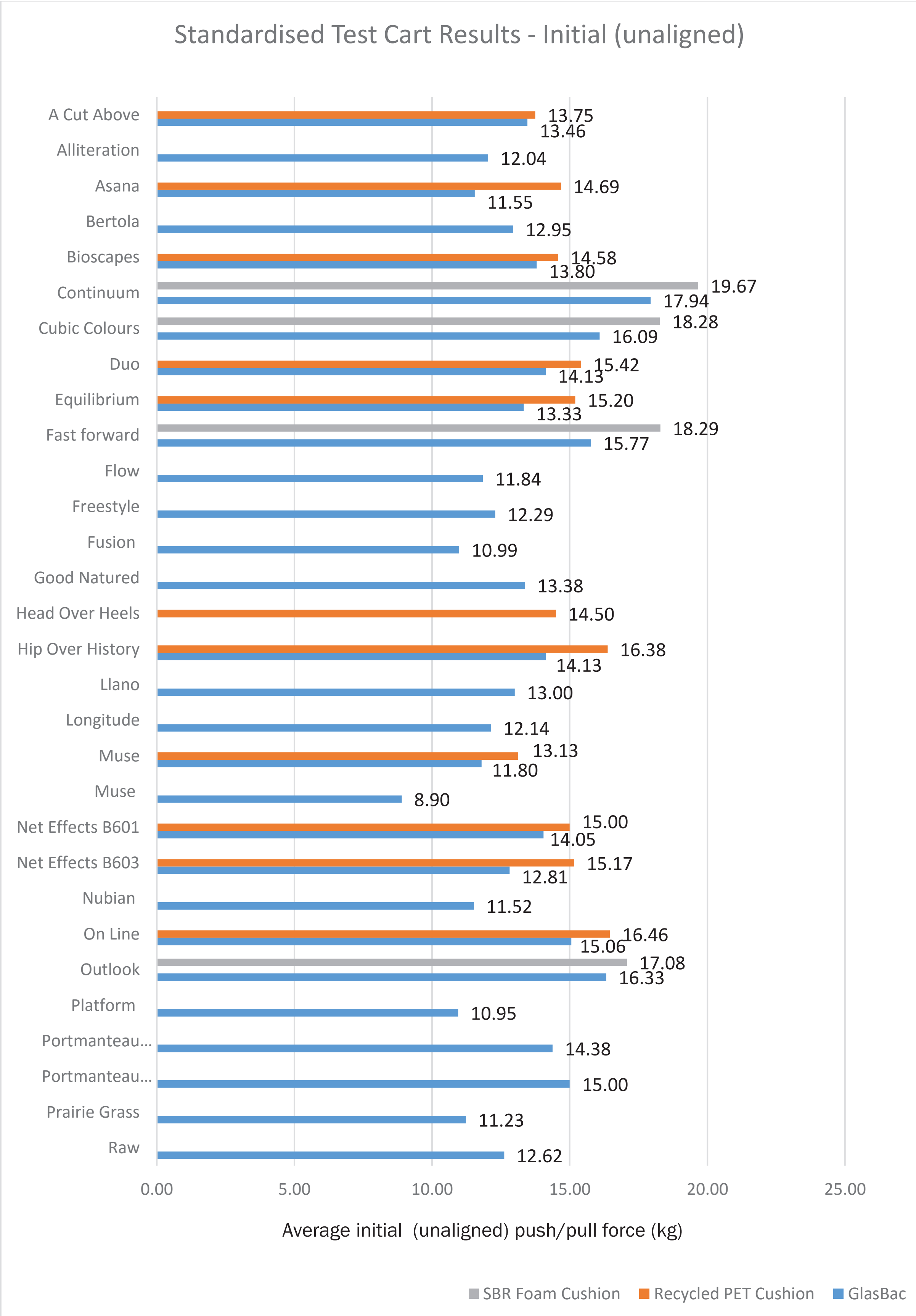
- *An initial pull* force of 12 kg is within the capability of 75% of the female working population for a 61 metre pull every 2 minutes, or for a 7.6 metre pull every 15 seconds, or for a 2.1 metre pull every 6 seconds.

- *An initial push* force of 12 kg is within the capability of 75% of the female working population for a 61 metre pull every 2 minutes, or for a 7.6 metre pull every 15 seconds, or for a 2.1 metre pull every 6 seconds.

The initial forces to pull the walker was below 5 kg.

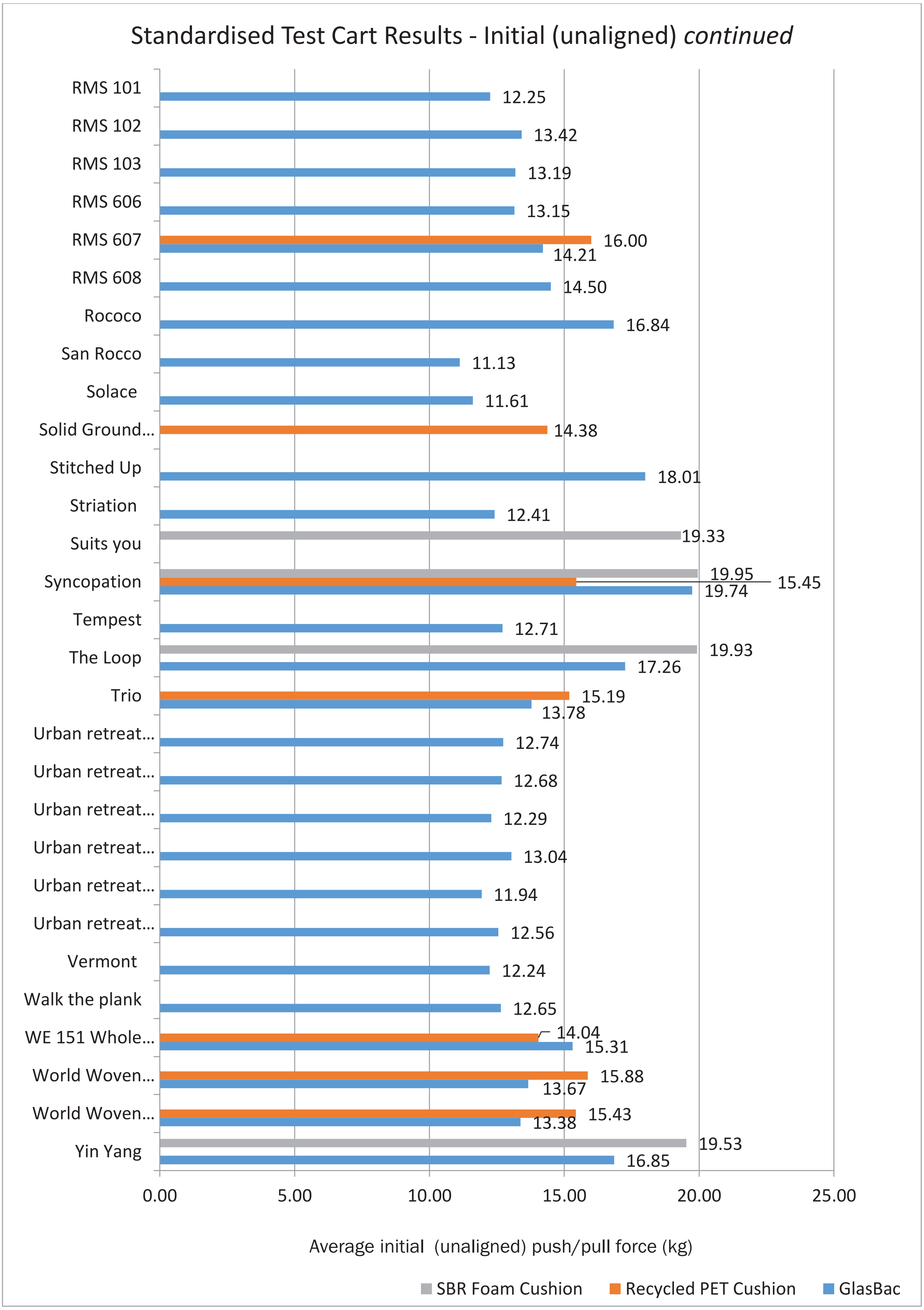
The maximum initial force measured for pushing the standardised test cart was just below 20 kg on all of the floor coverings. This is within the range recommended by Lawson and Potiki (1994) of 17 to 21 kg for initial force for a female worker on her own.

The Standardised test cart results shown in Figure 15 and Figure 16 for initial (unaligned) push/pull forces were all measured as 20 kg or less. Providing acceptable initial force across the carpet types tested for the generic rolling equipment calibrated.



Standardised Test Cart Results - Initial (unaligned)
A Cut Above
Alliteration
Asana
Bertola
Bioscapes
Continuum
Cubic Colours
Duo
Equilibrium
Fast forward
Flow
Freestyle
Fusion
Good Natured
Head Over Heels
Hip Over History
Llano
Longitude
Muse
Muse
Net Effects B601
Net Effects B603
Nubian
On Line
Outlook
Platform
Portmanteau...
Portmanteau...
Prairie Grass
Raw
13.75
13.46
12.04
14.69
11.55
12.95
14.58
13.80
19.67
17.94
18.28
16.09
15.42
14.13
15.20
13.33
18.29
15.77
11.84
12.29
10.99
13.38
14.50
16.38
14.13
13.00
12.14
13.13
11.80
8.90
15.00
14.05
15.17
12.81
11.52
16.46
15.06
17.08
16.33
10.95
14.38
15.00
11.23
12.62
0.00
5.00
10.00
15.00
20.00
25.00
Average initial (unaligned) push/pull force (kg)
SBR Foam Cushion
Recycled PET Cushion
GlasBac

Figure 15



Standardised Test Cart Results - Initial (unaligned) *continued*
RMS 101
RMS 102
RMS 103
RMS 606
RMS 607
RMS 608
Rococo
San Rocco
Solace
Solid Ground...
Stitched Up
Striation
Suits you
Syncopation
Tempest
The Loop
Trio
Urban retreat...
Urban retreat...
Urban retreat...
Urban retreat...
Urban retreat...
Urban retreat...
Vermont
Walk the plank
WE 151 Whole...
World Woven...
World Woven...
Yin Yang
12.25
13.42
13.19
13.15
16.00
14.21
14.50
16.84
11.13
11.61
14.38
18.01
12.41
19.33
19.95
15.45
19.74
12.71
19.93
17.26
15.19
13.78
12.74
12.68
12.29
13.04
11.94
12.56
12.24
12.65
14.04
15.31
15.88
13.67
15.43
13.38
19.53
16.85
0.00
5.00
10.00
15.00
20.00
25.00
Average initial (unaligned) push/pull force (kg)
SBR Foam Cushion
Recycled PET Cushion
GlasBac

Figure 16

Carpet Backing Comparison for initial (unaligned) push/pull forces

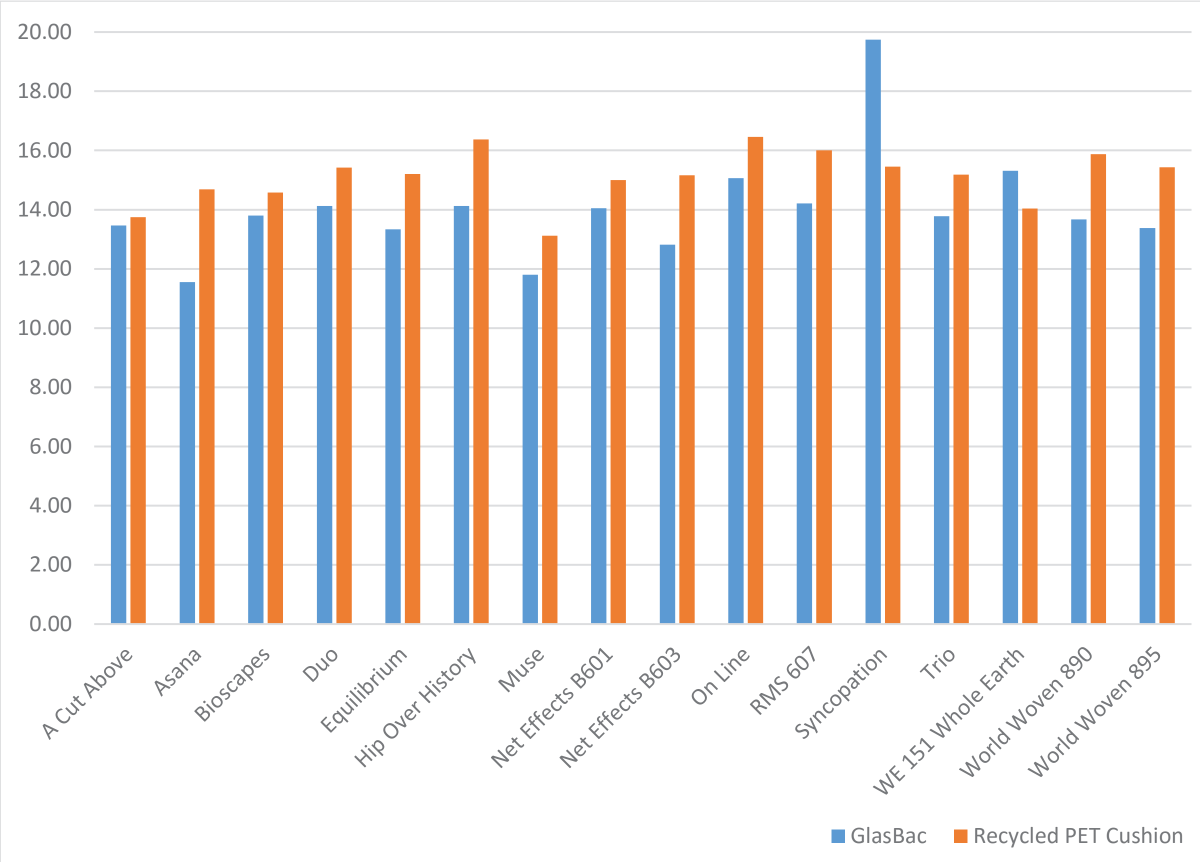


Figure 17

The variation between the *Recycled PET Cushion-back* material and the *GlasBac* for the initial force required when the castors are not aligned in the direction of travel showed that most of the carpets with Cushion-back required more force.

Synocopation and WE151 Whole Earth carpets showed a higher force result on the GlasBac. The turning resistance of the castors produced by the softer backing, generally takes greater forces to realigned the castors initially.

Conclusions

This three-part study has provided a comparison of pulling (and assumed equal pushing) forces, for a wide range of carpets currently available for institutional settings. Accordingly, it is hoped to be of practical value in making workplaces safer.

The items of equipment selected for Studies One and Two are indicative of what exists in health and aged care agencies, but they do not represent the entire range of beds, trolleys or equipment that is used in those settings. Nor does the simulated patient weight of 70 kg represent the extremes of patient weight likely to be encountered in health and aged care work. However, since the items of test equipment remained the same throughout Studies One and Two, the tests do provide an objective comparison of the relative characteristics of the different floor surfaces tested.

In Study Three, the results across the range of hospital equipment tested in Studies One and Two were used to calibrate a standardised test cart. The test cart was designed with specific castors and weights to simulate the type of wheeled equipment used within institutional settings. Its use has increased the accuracy of results, reduced the variability in test data, allowed the consolidation of results across all the studies, and enabled future testing along consistent lines.

The forces with the wheels not initially aligned were variable, but were generally considerably higher than the initial forces with the wheels aligned. This suggests that caution should be exercised when manoeuvring heavy equipment in confined spaces. Mobile hoists have particular characteristics when turning, including small wheels and a mechanical disadvantage, which can make their use in confined spaces difficult on most carpets. A design alternative being used in many new buildings is to fit ceiling-mounted, track-based hoists over the beds of dependent residents, so that commode chairs can be used for transferring dependent residents between bed and ensuite or day chair.

Over all of the test measurements, SBR foam Cushion-backed carpets required generally higher forces than the same carpet with Glasbac. The effect was most pronounced with the hoist when its wheels were set at right angles to the intended direction of travel. Initial push forces in this configuration were approximately 10 to 20 percent higher for the Cushion-back version compared to the same carpet with Glasbac. This suggests that Glasbac type carpets are preferred in rooms where mobile hoists are used to transfer residents from beds, and in other situations where manoeuvring in tight spaces is required.

The recycled PET Cushion-back showed similar results when compared with the same carpet with Glasbac. The variations seen with the SBR foam Cushion-back were not as significant with the recycled PET Cushion-back. The measured initial forces with the castors aligned showed six of the sixteen carpets tested performed marginally better on the Cushion-back. However, on the unaligned initial force test this reduced to two of the sixteen carpets.

Comparing the different items of equipment, the bed consistently required the highest forces, followed by the mobile hoist. The testing suggested that larger-diameter wheels generally appear to reduce the resistance to pushing on soft surfaces.

Use of the Snook Tables

The Snook tables have been used as the prime criterion of acceptability in these tests, because they have been validated against epidemiological injury data. A research report on ergonomics guidelines for manually handled trolleys in the health industry, conducted for the Central Sydney Area Health Service by Lawson and Potiki (1994), analysed a range of research including those of Snook and colleagues, and recommended the following values for pushing/pulling of trolleys, for a mixed male/female workforce:

- 17 to 21 kg for initial force
- 6 to 12 kg for sustained force

None of the initial forces (wheels aligned) exceeded 20 kg across all three studies for the carpet samples tested.

There are a number of factors other than push forces for wheeled equipment, that need to be considered when choosing floor coverings in various parts of health and aged care buildings. These naturally include the cost of installation, the cost of maintenance and cleaning, the ease of cleaning, infection control (generally not a major issue), continence issues, slips, trips and falls (likelihood and consequences), fatigue on feet and legs, noise control, glare control, and aesthetics. Further guidance is available in the current edition of the WorkSafe Victoria publication A Guide to Designing Workplaces for Safer Handling of People, which is available at www.worksafe.vic.gov.au.

Health and aged care facilities are workplaces, and are governed by laws including the occupational health and safety acts under each state or territory's legislation. These statutes generally include some form of regulation dealing with manual handling safety, and which is generally similar to the National Standard for Manual Handling. This Standard requires employers to assess manual handling hazards, and to reduce any risks are far as practicable. The approach in this study has been consistent with this, and has used the tables of acceptable forces published by Snook and Ciriello (1991) as a means of assessing the risk of manual handling injury from pushing wheeled equipment on carpet floor coverings that may be considered for use in health and aged care facilities.

References

Lawson, J & Potiki, J (1994). [Development of ergonomic guidelines for manually handled trolleys in the health industry (Central Sydney Area Health Service)].

Snook, S & Ciriello, V (1991). 'The design of manual handling tasks; revised tables of maximum acceptable weights and forces'. Ergonomics 34.9:1197 – 1213.

WorkSafe Victoria. A Guide to Designing Workplaces for Safer Handling of People, (3rd Edition, 2007), available at www.worksafe.vic.gov.au

Appendix A

Individual Equipment Testing – sustained force

Note: Values shaded blue were calculated from calibrated test cart, ratios are available in Appendix D.

Carpet	Backing	Installation Method	Bed	Wheel chair	Mobile Hoist	Walker	Food Trolley	Test Cart
A Cut Above	Recycled PET Cushion	Random	13.72	2.93	8.41	0.84	3.35	6.50
A Cut Above	GlasBac	Random	10.73	2.29	6.58	0.66	2.62	5.08
Alliteration	Glasbac	Directional	11.05	2.29	6.47	0.60	3.33	5.24
Asana	Glasbac	Random	11.67	2.08	6.70	0.75	2.67	5.53
Asana	Recycled PET Cushion	Random	12.66	2.71	7.77	0.77	3.10	6.00
Bertola	Glasbac	Directional	11.83	2.88	7.57	1.08	3.38	5.61
Bioscapes	Recycled PET Cushion	Quarter Turn	10.90	2.33	6.69	0.67	2.67	5.17
Bioscapes	GlasBac	Quarter Turn	14.77	3.16	9.06	0.90	3.61	7.00
Broadloom	Hessian	Directional	10.85	7.36				5.14
Continuum	SBR Foam Cushion	Directional	10.26	7.76	2.55			4.86
Continuum	Glasbac	Directional	8.06	6.42	2.44			3.82
Cubic Colours	SBR Foam Cushion	Directional	8.43	7.19	2.07	1.10	5.48	4.00
Cubic Colours	Glasbac	Directional	6.62	5.90	2.48	1.46	4.45	3.14
Duo	Recycled PET Cushion	Ashlar	13.01	2.78	7.98	0.80	3.18	6.17
Duo	GlasBac	Ashlar	10.73	2.29	6.58	0.66	2.62	5.08
Equilibrium	Recycled PET Cushion	Quarter Turn	12.03	2.57	7.38	0.74	2.94	5.70
Equilibrium	GlasBac	Quarter Turn	8.44	1.80	5.18	0.52	2.06	4.00
Fast forward	SBR Foam Cushion	Directional	9.97	7.40	3.01			4.73
Fast forward	Glasbac	Directional	8.00	6.72	2.29			3.79
Flow	Glasbac	Directional	11.08	2.50	6.33	0.96	2.50	5.25
Freestyle	Glasbac	Directional	11.29	2.33	6.93	0.79	2.67	5.35
Fusion	Glasbac	Quarter turn	10.00	1.79	7.31	0.54	1.88	4.74
Good Natured	GlasBac	Ashlar	10.11	2.16	6.20	0.62	2.47	4.79

Head Over Heels	Recycled PET Cushion	Random	12.31	2.63	7.55	0.75	3.01	5.83
Hip Over History	Recycled PET Cushion	Random	12.66	2.71	7.77	0.77	3.10	6.00
Hip Over History	GlasBac	Random	10.90	2.33	6.69	0.67	2.67	5.17
Llano	GlasBac	Directional	7.79	1.66	4.78	0.48	1.90	3.69
Longitude	Glasbac	Quarter Turn	11.71	2.55	7.31	0.62	2.57	5.55
Muse	Recycled PET Cushion	Quarter Turn	11.61	2.48	7.12	0.71	2.84	5.50
Muse	GlasBac	Ashlar	9.90	2.11	6.07	0.61	2.42	4.69
Muse	Glasbac	Ashlar	7.50	2.92	7.40	1.00	3.50	3.55
Net Effects B601	Recycled PET Cushion	Random	12.31	2.63	7.55	0.75	3.01	5.83
Net Effects B601	Glasbac	Random	12.40	2.65	7.61	0.76	3.03	5.88
Net Effects B603	Recycled PET Cushion	Random	10.55	2.25	6.47	0.65	2.58	5.00
Net Effects B603	Glasbac	Random	11.61	2.48	7.12	0.71	2.84	5.50
Nubian	Glasbac	Quarter turn	11.25	2.42	6.92	0.83	2.50	5.33
On Line	Recycled PET Cushion	Ashlar	11.43	2.44	7.01	0.70	2.79	5.42
On Line	GlasBac	Ashlar	10.90	2.33	6.69	0.67	2.67	5.17
Outlook	SBR Foam Cushion	Directional	9.77	7.82	3.00			4.63
Outlook	Glasbac	Directional	8.96	6.35	2.39			4.25
Platform	Glasbac	Directional	11.00	2.08	6.75	0.79	2.50	5.21
Portmanteau PM01	GlasBac	Ashlar	10.37	2.22	6.36	0.63	2.54	4.92
Portmanteau PM049	GlasBac	Ashlar	9.85	2.10	6.04	0.60	2.41	4.67
Prairie Grass	GlasBac	Directional	10.55	2.25	6.47	0.65	2.58	5.00
Raw	Glasbac	Random	11.83	2.45	7.47	0.75	3.00	5.61
RMS 101	GlasBac	Quarter Turn	10.55	2.25	6.47	0.65	2.58	5.00
RMS 102	GlasBac	Quarter Turn	9.85	2.10	6.04	0.60	2.41	4.67
RMS 103	GlasBac	Quarter Turn	12.40	2.65	7.61	0.76	3.03	5.88
RMS 606	GlasBac	Quarter Turn	11.08	2.37	6.80	0.68	2.71	5.25

RMS 607	Recycled PET Cushion	Quarter Turn	14.35	3.07	8.80	0.88	3.51	6.80
RMS 607	GlasBac	Quarter Turn	13.29	2.84	8.16	0.81	3.25	6.30
RMS 608	GlasBac	Quarter Turn	12.31	2.63	7.55	0.75	3.01	5.83
Rococo	Glasbac	Directional	9.70	7.03	3.21			4.60
San Rocco	Glasbac	Directional	12.58	2.53	7.33	0.88	2.81	5.96
Solace	Glasbac	Directional	11.88	2.48	6.63	0.75	2.57	5.63
Solid Ground UR303	Recycled PET Cushion	Ashlar	10.37	2.22	6.36	0.63	2.54	4.92
Stitched Up	Glasbac	Directional	9.76	6.76	2.67			4.63
Striation	Glasbac	Directional	11.75	2.83	7.25	0.75	2.83	5.57
Suits you	SBR Foam Cushion	Directional	9.46	8.22	2.82			4.48
Syncopation	SBR Foam Cushion	Directional	9.82	8.34	1.87	0.90	5.45	4.65
Syncopation	Glasbac	Directional	9.14	7.05	2.50	1.26	5.14	4.33
Syncopation	Recycled PET Cushion	Quarter Turn	13.45	2.87	8.25	0.82	3.29	6.38
Tempest	Glasbac	Directional	12.04	2.58	7.45	0.48	3.29	5.71
The Loop	SBR Foam Cushion	Directional	10.92	7.80	3.25			5.18
The Loop	Glasbac	Directional	8.80	6.55	2.25			4.17
Trio	Recycled PET Cushion	Ashlar	11.08	2.37	6.80	0.68	2.71	5.25
Trio	GlasBac	Ashlar	11.61	2.48	7.12	0.71	2.84	5.50
Urban retreat 101	Glasbac	Quarter turn	12.50	2.42	7.75	1.13	3.25	5.92
Urban retreat 201	Glasbac	Quarter turn	12.33	3.08	7.52	0.75	3.00	5.84
Urban retreat 202	Glasbac	Directional	11.50	2.50	7.08	0.75	3.00	5.45
Urban retreat 203	Glasbac	Quarter turn	12.33	2.83	7.38	0.67	3.50	5.84
Urban retreat 302	Glasbac	Quarter turn	11.42	2.58	6.67	0.75	2.92	5.41
Urban retreat 303	Glasbac	Directional	12.21	2.50	6.92	0.75	2.83	5.79
Vermont	Glasbac	Directional	12.75	2.50	7.45	0.67	3.08	6.04
Walk the plank	Glasbac	Directional	13.33	2.79	7.53	0.75	3.25	6.32
WE 151 Whole Earth	GlasBac	Ashlar	10.90	2.33	6.69	0.67	2.67	5.17

WE 151 Whole Earth	Recycled PET Cushion	Ashlar	9.14	1.95	5.61	0.56	2.24	4.33
World Woven 890	Recycled PET Cushion	Ashlar	11.61	2.48	7.12	0.71	2.84	5.50
World Woven 890	GlasBac	Ashlar	12.13	2.59	7.44	0.74	2.97	5.75
World Woven 895	Recycled PET Cushion	Ashlar	11.96	2.55	7.34	0.73	2.92	5.67
World Woven 895	GlasBac	Ashlar	8.62	1.84	5.29	0.53	2.11	4.08
Yin Yang	SBR Foam Cushion	Directional	10.19	8.09	3.14			4.83
Yin Yang	Glasbac	Directional	9.21	7.09	2.90			4.36

Appendix B

Individual Equipment Testing – initial force – castors aligned in direction of travel

Note: Values shaded blue were calculated from calibrated test cart, ratios are available in Appendix D.

Carpet	Backing	Installation Method	Bed	Wheel chair	Mobile Hoist	Walker	Food Trolley	Test Cart
A Cut Above	Recycled PET Cushion	Random	16.25	4.55	11.86	1.61	5.38	12.50
A Cut Above	GlasBac	Random	15.99	4.48	11.67	1.58	5.29	12.30
Alliteration	Glasbac	Directional	16.01	4.50	7.67	1.25	4.96	12.32
Asana	Glasbac	Random	14.63	6.38	9.63	3.33	8.67	11.25
Asana	Recycled PET Cushion	Random	16.25	4.55	11.86	1.61	5.38	12.50
Bertola	Glasbac	Directional	14.67	4.63	11.63	1.21	4.25	11.28
Bioscapes	Recycled PET Cushion	Quarter Turn	16.49	4.62	12.04	1.63	5.46	12.69
Bioscapes	GlasBac	Quarter Turn	15.67	4.39	11.43	1.55	5.19	12.05
Continuum	SBR Foam Cushion	Directional	17.22	10.86	4.62			13.25
Continuum	Glasbac	Directional	16.79	9.80	3.94			12.92
Cubic Colours	SBR Foam Cushion	Directional	15.48	10.53	3.75	1.80	7.86	11.91
Cubic Colours	Glasbac	Directional	15.48	8.97	3.62	2.42	6.74	11.91
Duo	Recycled PET Cushion	Ashlar	18.40	5.15	13.43	1.82	6.09	14.16
Duo	GlasBac	Ashlar	16.94	4.75	12.37	1.68	5.61	13.03
Equilibrium	Recycled PET Cushion	Quarter Turn	16.12	4.52	11.77	1.60	5.34	12.40
Equilibrium	GlasBac	Quarter Turn	16.03	4.49	11.70	1.59	5.31	12.33
Fast forward	SBR Foam Cushion	Directional	18.03	10.35	4.12			13.87
Fast forward	Glasbac	Directional	16.14	10.04	3.99			12.42
Flow	Glasbac	Directional	13.33	4.71	10.04	1.54	4.75	10.25
Freestyle	Glasbac	Directional	13.71	4.38	11.00	1.50	4.13	10.55
Fusion	Glasbac	Quarter turn	15.79	4.63	12.38	1.50	5.46	12.15
Good Natured	GlasBac	Ashlar	17.31	4.85	12.63	1.71	5.73	13.31
Head Over Heels	Recycled PET Cushion	Random	16.03	4.49	11.70	1.59	5.31	12.33
Hip Over History	Recycled PET Cushion	Random	14.04	3.93	10.25	1.39	4.65	10.80
Hip Over History	GlasBac	Random	15.44	4.32	11.27	1.53	5.11	11.88
Llano	GlasBac	Directional	15.05	4.22	10.99	1.49	4.98	11.58

Longitude	Glasbac	Quarter Turn	14.88	4.49	11.33	1.25	4.97	11.45
Muse	Recycled PET Cushion	Quarter Turn	16.58	4.64	12.10	1.64	5.49	12.75
Muse	GlasBac	Ashlar	13.33	3.73	9.73	1.32	4.41	10.25
Muse	Glasbac	Ashlar	10.46	2.83	11.25	1.25	5.29	8.05
Net Effects B601	Recycled PET Cushion	Random	17.31	4.85	12.63	1.71	5.73	13.31
Net Effects B601	Glasbac	Random	17.88	5.01	13.05	1.77	5.92	13.75
Net Effects B603	Recycled PET Cushion	Random	15.38	4.31	11.23	1.52	5.09	11.83
Net Effects B603	Glasbac	Random	16.38	4.59	11.96	1.62	5.42	12.60
Nubian	Glasbac	Quarter turn	14.58	2.83	10.17	1.58	4.50	11.22
On Line	Recycled PET Cushion	Ashlar	19.74	5.53	14.41	1.95	6.54	15.19
On Line	GlasBac	Ashlar	17.31	4.85	12.63	1.71	5.73	13.31
Outlook	SBR Foam Cushion	Directional	16.98	10.62	4.71			13.06
Outlook	Glasbac	Directional	16.45	9.50	3.92			12.65
Platform	Glasbac	Directional	14.42	2.83	10.08	1.42	4.50	11.09
Portmanteau PM01	GlasBac	Ashlar	17.39	4.87	12.69	1.72	5.76	13.38
Portmanteau PM049	GlasBac	Ashlar	17.06	4.78	12.45	1.69	5.65	13.13
Prairie Grass	GlasBac	Directional	13.20	3.70	9.63	1.31	4.37	10.15
Raw	Glasbac	Random	14.42	4.33	10.54	1.13	4.94	11.09
RMS 101	GlasBac	Quarter Turn	15.67	4.39	11.43	1.55	5.19	12.05
RMS 102	GlasBac	Quarter Turn	17.33	4.86	12.65	1.72	5.74	13.33
RMS 103	GlasBac	Quarter Turn	15.93	4.46	11.62	1.58	5.27	12.25
RMS 606	GlasBac	Quarter Turn	16.90	4.73	12.34	1.67	5.60	13.00
RMS 607	Recycled PET Cushion	Quarter Turn	18.40	5.15	13.43	1.82	6.09	14.15
RMS 607	GlasBac	Quarter Turn	15.40	4.31	11.24	1.52	5.10	11.84
RMS 608	GlasBac	Quarter Turn	15.93	4.46	11.62	1.58	5.27	12.25
Rococo	Glasbac	Directional	17.72	10.41	4.44			13.63
San Rocco	Glasbac	Directional	13.58	4.38	10.54	1.54	4.93	10.45
Solace	Glasbac	Directional	13.88	4.83	9.71	1.46	4.50	10.68
Solid Ground UR303	Recycled PET Cushion	Ashlar	17.17	4.81	12.53	1.70	5.69	13.21
Stitched Up	Glasbac	Directional	16.11	10.07	3.91			12.39
Striation	Glasbac	Directional	14.63	5.63	11.83	1.50	5.04	11.25
Suits you	SBR Foam Cushion	Directional	16.75	11.12	4.61			12.88

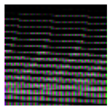
Syncopation	SBR Foam Cushion	Directional	18.22	11.46	3.86	1.89	7.75	14.02
Syncopation	Glasbac	Directional	18.02	10.61	4.09	2.35	8.69	13.86
Syncopation	Recycled PET Cushion	Quarter Turn	18.02	5.05	13.15	1.78	5.97	13.86
Tempest	Glasbac	Directional	14.93	4.82	10.58	1.29	4.73	11.48
The Loop	SBR Foam Cushion	Directional	18.28	10.79	5.39			14.06
The Loop	Glasbac	Directional	16.60	9.27	3.59			12.77
Trio	Recycled PET Cushion	Ashlar	17.50	4.90	12.77	1.73	5.79	13.46
Trio	GlasBac	Ashlar	18.01	5.04	13.15	1.78	5.96	13.85
Urban retreat 101	Glasbac	Quarter turn	15.46	2.83	11.50	1.50	4.92	11.89
Urban retreat 201	Glasbac	Quarter turn	15.38	5.38	13.21	1.58	5.38	11.83
Urban retreat 202	Glasbac	Directional	15.38	5.08	11.21	1.63	5.08	11.83
Urban retreat 203	Glasbac	Quarter turn	16.54	5.13	11.54	1.38	5.04	12.72
Urban retreat 302	Glasbac	Quarter turn	14.38	5.13	10.67	1.63	4.63	11.06
Urban retreat 303	Glasbac	Directional	15.04	4.92	11.04	1.58	4.54	11.57
Vermont	Glasbac	Directional	14.88	4.88	10.71	1.38	4.96	11.45
Walk the plank	Glasbac	Directional	15.25	4.96	11.50	1.38	4.96	11.73
WE 151 Whole Earth	GlasBac	Ashlar	18.42	5.16	13.44	1.82	6.10	14.17
WE 151 Whole Earth	Recycled PET Cushion	Ashlar	17.52	4.91	12.79	1.73	5.80	13.48
World Woven 890	Recycled PET Cushion	Ashlar	17.12	4.79	12.49	1.69	5.67	13.17
World Woven 890	GlasBac	Ashlar	16.79	4.70	12.26	1.66	5.56	12.92
World Woven 895	Recycled PET Cushion	Ashlar	17.83	5.00	13.02	1.77	5.91	13.72
World Woven 895	GlasBac	Ashlar	16.03	4.49	11.70	1.59	5.31	12.33
Yin Yang	SBR Foam Cushion	Directional	18.50	11.09	4.78			14.23
Yin Yang	Glasbac	Directional	16.96	10.41	4.49			13.05

Appendix C

Individual Equipment Testing – initial force – castors not aligned in direction of travel

Note: Values shaded blue were calculated from calibrated test cart, ratios are available in Appendix D.

Carpet	Backing	Installation Method	Bed	Wheel chair	Mobile Hoist	Walker	Food Trolley	Test Cart
A Cut Above	Recycled PET Cushion	Random	19.25	5.94	15.16	3.03	9.77	13.75
A Cut Above	GlasBac	Random	18.85	5.82	14.84	2.97	9.57	13.46
Alliteration	Glasbac	Directional	16.85	6.46	11.13	2.25	8.96	12.04
Asana	Glasbac	Random	16.17	7.05	12.21	3.42	8.58	11.55
Asana	Recycled PET Cushion	Random	20.56	6.35	16.19	3.24	10.44	14.69
Bertola	Glasbac	Directional	18.13	7.54	14.29	2.42	9.00	12.95
Bioscapes	Recycled PET Cushion	Quarter Turn	20.42	6.30	16.08	3.22	10.36	14.58
Bioscapes	GlasBac	Quarter Turn	19.32	5.96	15.21	3.04	9.81	13.80
Continuum	SBR Foam Cushion	Directional	27.54	14.67	6.92			19.67
Continuum	Glasbac	Directional	25.12	12.11	5.31			17.94
Cubic Colours	SBR Foam Cushion	Directional	25.59	13.48	5.07	4.10	11.80	18.28
Cubic Colours	Glasbac	Directional	22.52	11.53	4.84	4.62	9.97	16.09
Duo	Recycled PET Cushion	Ashlar	21.58	6.66	16.99	3.40	10.96	15.42
Duo	GlasBac	Ashlar	19.78	6.10	15.57	3.11	10.04	14.13
Equilibrium	Recycled PET Cushion	Quarter Turn	21.28	6.57	16.76	3.35	10.80	15.20
Equilibrium	GlasBac	Quarter Turn	18.67	5.76	14.70	2.94	9.48	13.33
Fast forward	SBR Foam Cushion	Directional	25.61	13.06	6.08			18.29
Fast forward	Glasbac	Directional	22.08	11.99	5.54			15.77
Flow	Glasbac	Directional	16.58	7.25	12.58	2.92	6.08	11.84
Freestyle	Glasbac	Directional	17.21	7.53	13.17	2.46	8.25	12.29
Fusion	Glasbac	Quarter turn	15.38	4.33	12.33	1.46	5.71	10.99
Good Natured	GlasBac	Ashlar	18.73	5.78	14.74	2.95	9.51	13.38
Head Over Heels	Recycled PET Cushion	Random	20.30	6.27	15.98	3.20	10.30	14.50
Hip Over History	Recycled PET Cushion	Random	22.93	7.08	18.05	3.61	11.64	16.38
Hip Over History	GlasBac	Random	19.78	6.10	15.57	3.11	10.04	14.13
Llano	GlasBac	Directional	18.20	5.62	14.33	2.87	9.24	13.00
Longitude	Glasbac	Quarter Turn	17.00	6.46	13.29	2.49	7.68	12.14



Muse	Recycled PET Cushion	Quarter Turn	18.38	5.67	14.47	2.89	9.33	13.13
Muse	GlasBac	Ashlar	16.52	5.10	13.01	2.60	8.39	11.80
Muse	Glasbac	Ashlar	12.46	2.83	12.38	2.88	9.75	8.90
Net Effects B601	Recycled PET Cushion	Random	21.00	6.48	16.54	3.31	10.66	15.00
Net Effects B601	Glasbac	Random	19.67	6.07	15.49	3.10	9.98	14.05
Net Effects B603	Recycled PET Cushion	Random	21.23	6.55	16.72	3.34	10.78	15.17
Net Effects B603	Glasbac	Random	17.94	5.54	14.12	2.82	9.11	12.81
Nubian	Glasbac	Quarter turn	16.13	2.83	12.13	2.79	7.67	11.52
On Line	Recycled PET Cushion	Ashlar	23.04	7.11	18.14	3.63	11.70	16.46
On Line	GlasBac	Ashlar	21.09	6.51	16.60	3.32	10.70	15.06
Outlook	SBR Foam Cushion	Directional	23.91	13.53	6.06			17.08
Outlook	Glasbac	Directional	22.86	12.36	5.62			16.33
Platform	Glasbac	Directional	15.33	2.83	10.75	2.50	7.95	10.95
Portmanteau PM01	GlasBac	Ashlar	20.13	6.21	15.85	3.17	10.22	14.38
Portmanteau PM049	GlasBac	Ashlar	21.00	6.48	16.54	3.31	10.66	15.00
Prairie Grass	GlasBac	Directional	15.72	4.85	12.38	2.48	7.98	11.23
Raw	Glasbac	Random	17.67	7.58	14.54	3.67	9.29	12.62
RMS 101	GlasBac	Quarter Turn	17.15	5.29	13.50	2.70	8.71	12.25
RMS 102	GlasBac	Quarter Turn	18.78	5.80	14.79	2.96	9.53	13.42
RMS 103	GlasBac	Quarter Turn	18.46	5.70	14.54	2.91	9.37	13.19
RMS 606	GlasBac	Quarter Turn	18.41	5.68	14.50	2.90	9.35	13.15
RMS 607	Recycled PET Cushion	Quarter Turn	22.40	6.91	17.64	3.53	11.37	16.00
RMS 607	GlasBac	Quarter Turn	19.89	6.14	15.66	3.13	10.10	14.21
RMS 608	GlasBac	Quarter Turn	20.30	6.27	15.98	3.20	10.30	14.50
Rococo	Glasbac	Directional	23.57	13.46	6.18			16.84
San Rocco	Glasbac	Directional	15.58	6.48	12.96	2.51	8.24	11.13
Solace	Glasbac	Directional	16.25	7.08	11.96	2.38	8.33	11.61
Solid Ground UR303	Recycled PET Cushion	Ashlar	20.13	6.21	15.85	3.17	10.22	14.38
Stitched Up	Glasbac	Directional	25.21	11.63	5.78			18.01
Striation	Glasbac	Directional	17.38	8.33	14.42	2.71	9.21	12.41
Suits you	SBR Foam Cushion	Directional	27.06	13.47	6.18			19.33
Syncopation	SBR Foam Cushion	Directional	27.93	14.46	6.06	4.34	12.13	19.95

Syncopation	Glasbac	Directional	27.64	13.14	6.16	5.08	11.76	19.74
Syncopation	Recycled PET Cushion	Quarter Turn	21.63	6.68	17.03	3.41	10.98	15.45
Tempest	Glasbac	Directional	17.79	7.52	12.75	2.21	9.29	12.71
The Loop	SBR Foam Cushion	Directional	27.90	14.12	7.16			19.93
The Loop	Glasbac	Directional	24.16	11.90	5.61			17.26
Trio	Recycled PET Cushion	Ashlar	21.26	6.56	16.74	3.35	10.79	15.19
Trio	GlasBac	Ashlar	19.29	5.95	15.19	3.04	9.79	13.78
Urban retreat 101	Glasbac	Quarter turn	17.83	2.83	15.29	2.67	8.88	12.74
Urban retreat 201	Glasbac	Quarter turn	17.75	8.67	14.54	2.96	9.17	12.68
Urban retreat 202	Glasbac	Directional	17.21	6.71	15.33	2.96	8.83	12.29
Urban retreat 203	Glasbac	Quarter turn	18.25	7.53	14.33	3.04	9.25	13.04
Urban retreat 302	Glasbac	Quarter turn	16.71	7.33	14.21	2.83	9.13	11.94
Urban retreat 303	Glasbac	Directional	17.58	7.13	14.58	2.67	8.83	12.56
Vermont	Glasbac	Directional	17.13	7.51	12.58	2.50	9.04	12.24
Walk the plank	Glasbac	Directional	17.71	7.92	15.25	4.00	9.75	12.65
WE 151 Whole Earth	GlasBac	Ashlar	21.44	6.62	16.88	3.38	10.88	15.31
WE 151 Whole Earth	Recycled PET Cushion	Ashlar	19.66	6.07	15.48	3.10	9.98	14.04
World Woven 890	Recycled PET Cushion	Ashlar	22.23	6.86	17.50	3.50	11.28	15.88
World Woven 890	GlasBac	Ashlar	19.13	5.91	15.07	3.01	9.71	13.67
World Woven 895	Recycled PET Cushion	Ashlar	21.60	6.67	17.01	3.40	10.96	15.43
World Woven 895	GlasBac	Ashlar	18.73	5.78	14.74	2.95	9.51	13.38
Yin Yang	SBR Foam Cushion	Directional	27.34	15.53	7.50			19.53
Yin Yang	Glasbac	Directional	23.59	13.30	6.28			16.85

Appendix D

Standardised Test Cart

The standardised test cart was designed to create a consistent standard for rolling resistance testing.

It can be seen in the results from Studies One and Two that the variations in the hospital equipment used affected the results. The development of this apparatus was to improve the quality of the data by minimising the number of variables while improving the repeatability of the tests.

The standardised test cart as pictured below was constructed by affixing four castors to a square, stiffened piece of timber and adding 80 kg of weight. The castors were selected on two bases: first, to be representative of the most commonly-used types on hospital beds and service trolleys; second, to be specified such that tests on different carpets would produce results across a broad a range as possible (increasing comparative measurement accuracy). The advice of well-known castor manufacturers Fallshaw Wheels and Castors was sought in this regard, and their advice is gratefully acknowledged. The castor selected was of 125 mm diameter; flat-rimmed, 30 mm wide, of thermoplastic elastomer material (a rubber); not pneumatic, not locked, and with plain (not roller) bearings). These latter factors made “stiffer” carpets produce higher rolling resistance, and so overall accuracy was enhanced.

The standardised test cart was calibrated by retesting previous carpet samples from Studies One and Two with the test cart. These carpets were Bioscape, Equilibrium, Liano, Muse and Prairie Grass. Data obtained with the cart in Study Three was converted into data for each type of wheeled equipment, using the calibrating ratios obtained in Table 3.

Ratio between bed push force and other items of equipment.					
	Bed:cart	bed:w/chair	bed:hoist	bed:walker	bed:food trolley
sustained	2.11	4.68	1.63	16.34	4.09
aligned	1.3	3.57	1.37	10.1	3.02
unaligned	1.4	3.24	1.27	6.35	1.97

Table 3

The New South Wales WorkCover Authority initially published an industry safety advisory guide[2] with regard to trolleys and their use in work places, including advice on manual handling risks.

This guide provided advice on the type of wheels and castors used on trolleys and their impact on rolling resistance. The advice is intended for consumers who need to take a range of considerations into account. The discussion that follows considers these.

Wheel diameter

Larger wheels have lower rolling resistance than smaller ones, and are less affected by gaps, ridges and irregularities in the floor surface. A minimum diameter of 200 mm was recommended by Lawson and Potiki (1994) for all trolleys that have a laden weight over 200 kg or that are used outdoors. For other trolleys a minimum diameter of 125 mm is recommended. Small wheels may be acceptable for light trolleys that are moved only short distances on smooth floors.

Width and tyre profile

Narrower wheels and rounded tyre profiles roll and swivel more easily on hard surfaces. Wider treads may be necessary on soft carpets or where there are gaps that could catch a narrow wheel, for example, slots in drainage grates, or gaps between a lift and the floor. The width of the wheel will be partly dictated by the load rating required.

Tyre material

Hard materials such as cast iron and nylon have the lowest rolling resistance on hard, smooth surfaces such as concrete and are suitable in some industrial applications. However, hard wheels are more difficult to start when obstructions such as a stone or a gap in the floor is encountered. They can also be quite noisy.

Softer materials tend to even out the peak forces and may feel easier to push, even if the rolling resistance is higher on a smooth surface. Shock-absorbing materials such as rubber or polyurethane may be required for rougher floors and outdoor surfaces. In hospitals and hotels, non-marking rubber or polyurethane may be required to reduce noise and protect floor surfaces (nylon wheels are suitable if used exclusively on carpet).

Pneumatic tyres roll more easily over bumps and unpaved surfaces and may be preferred for some outdoor applications. However, they have a higher rolling resistance on smooth floors. They should be checked regularly to maintain the correct inflation pressure.

Some softer tyre materials may have high friction on some floor surfaces and make it hard for the wheels to swivel into alignment when the trolley is started, resulting in a higher initial force. For high load applications, it is important to try out different wheels on the floor where they will be used, before purchase.

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[2] No longer available.

Bearings

Sealed precision ball bearings provide the lowest rolling resistance. They are recommended for hand-pushed trolleys that are used frequently or over longer distances. Pre-lubrication and effective sealing ensure that the low rolling resistance is maintained without the need for further lubrication. There are other types of cheaper, lower grade ball bearings available, but these must be regularly lubricated.

Roller bearings are more commonly available for industrial castors but need periodic lubrication to maintain low rolling resistance. Plain metal bearings are acceptable on trolleys moved only infrequently over short distances, but the rolling resistance is higher than ball or roller bearings and increases markedly if not regularly lubricated. Plastic (usually nylon or acetal) plain bearings are acceptable for light loads and don't require lubrication.

Thread guards should be used to stop bearings from becoming clogged when used in environments where there are fabrics and lint, for example, in laundries. They are also reasonably effective at keeping dust and debris out of unsealed bearings, therefore requiring less need for frequent maintenance.

While taking cost and availability into account in the final selection of bearing types, one may find that the higher initial cost of sealed ball bearings is justified if push/pull forces are lower over the life of the trolley. It is suggested that known wheel and castor manufacturers such as Fallshaw be contacted for advice on selecting the type of wheels and bearings for a particular application.

Brakes

Brakes on at least two wheels are important if the trolley has to be loaded and unloaded on sloping surfaces, or where it is important to stop movement while transferring large items.

Castors are available with full brakes that prevent swivelling of the castor as well as rotation of the wheel.

Appendix E

Considerations in interpreting results

The measurements were carried out in all rounds of tests on a horizontal solid floor, and the results cannot be directly applied to sloping walkways. The forces to move or restrain trolleys on slopes are mainly determined by the steepness of the slope and the gross weight of the equipment. The total force is equal to that required to push the equipment on a horizontal surface, plus (or minus) a force component due to the slope. For a 200 kg total weight, the additional force due to pulling or pushing up slopes is as follows:

Slope of ramp	1:14	1:20	1:40	1:60	1:80
Additional force to push 200 kg total weight	14.2 kg	10.0 kg	5.0 kg	3.4 kg	2.5 kg

The hospital equipment used was not new in Rounds one and two of testing, but was in a good state of repair. Many hospitals have newer beds, or beds with large- diameter castors or dual-wheel castors, which are likely to offer less resistance. On the other hand, some beds are heavier, and some patients are heavier than 70 kg, which will increase the resistance to pushing. As noted in the report, it is not possible to replicate every type of bed and patient weight that may be encountered in health and aged care services throughout Australia. For this reason, in the case of sustained push forces, we have converted the results to those of a typical bed, based on all the tests we have done on vinyl floors.

In Study Two, the bed tested was fitted with 100 mm diameter wheels. From our previous experience with beds with 100 mm diameter wheels, they require increased forces for sustained pulling or pushing, compared with the sustained forces required for a bed fitted with larger (125 mm to 150 mm) wheels. The increase found in the sustained force required for a bed fitted with 100 mm castors was in the range of 3.7 kg.

The comparisons made in the preceding section have been based on an individual worker working solo. Many hospitals have practices in which two staff move the bed, with one person pushing from behind and the other person steering while walking forwards alongside the front of the bed. This helps to overcome the higher forces associated with initial movement from the stationary position, especially when the wheels are not first aligned.

The force measurements and recommendations are for straight-line movement. The forces required to manoeuvre equipment around corners are often greater, and the effort required may be greater due to awkward postures or to uneven loading on the person's arms. Beds and trolleys should preferably have their front wheels locked and the rear wheels free to swivel during cornering.

Mobile hoists are particularly difficult to manoeuvre in tight spaces such as fully-occupied bedrooms, because -

- The worker cannot always use an optimum posture.
- When turning, most of the pushing effort has to be delivered with one arm, often while pulling with the other arm, whereas straight-line pulling or pushing uses both arms equally and in the same direction.
- There is a mechanical disadvantage between the width of the handles and the wheelbase of the hoist, which can effectively double the force that has to be exerted when turning, noting that most of the pull or push force may be exerted by one hand.
- The wheels of mobile hoists are normally small in order to allow them to manoeuvre under beds, but this increases the resistance to movement on soft surfaces.
- The wheels may be out of alignment with the direction of travel when making sharp turns or when reversing the direction of travel.

There are no recommended acceptable forces for manoeuvring lifting machines in tight spaces. Based on the points above, an acceptable force may be roughly estimated to be of the order of one quarter of the acceptable straight-line push force (for the same duration and frequency), or typically around 5 kg for an initial force as part of a short 7.6 metre push, once per minute. If ceiling-mounted lifting systems are installed in high dependency bedrooms, there may be no need to manoeuvre lifting machines into position under beds, thus removing much of the tight turning. Standing lifters may still be used to take some residents to their ensuite occasionally during the day, but this may require less tight turning and manoeuvring, thus making it easier for staff, regardless of the floor covering.

Appendix F

Details of Study 1 and 2

Table 1 Study One - description of wheeled equipment tested

Item	Details	Load	
Bed	125 mm diameter single wheel Electrically operated, height adjustable bed, all wheels swivelling	70 kg	
Wheel chair	Invacare Action 2000 folding wheelchair , 600 mm rear; 200 mm front, swivelling	70 kg	
Lifting machine	Sling hoist, all four wheels swivelling, 100 mm front wheels	70 kg	
Walker	Front wheels swivelling, rear wheels fixed, 150 diameter	20 kg	
Meal trolley	20-tray meal trolley with solid rubber wheels with flat profile, all wheels swivelling, 100 mm diameter	10 kg	

Table 2 Study Two - description of wheeled equipment tested

Item	Details	Load	
Bed	100 mm diameter single wheel Electrically operated, height adjustable bed, all wheels swivelling	70 kg	
Wheel chair	Folding wheelchair, 600 mm rear wheels; 190 mm front swivelling wheels, tyre pressure 4.5 bar	70 kg	
Mobile hoist	Sling hoist, all four wheels swivelling, 80 mm front wheels, 130 mm rear wheels	70 kg	
Walker	Front wheels swivelling, rear wheels fixed, 150 mm diameter	20 kg	
Meal trolley	20-tray meal trolley with solid rubber wheels with flat profile, all wheels swivelling, 100 mm diameter	10 kg	

Table 3 Study One - details of floor coverings tested with health care equipment

	Carpet	Backing	Installation method
A	Bioscape	Glasbac	Directional
B	Continuum	Glasbac	Directional
C	Continuum	Cushion	Directional
D	Cubic Colours	Glasbac	Directional
E	Cubic Colours	Cushion	Directional
F	Fast forward	Glasbac	Directional
G	Fast forward	Cushion	Directional
H	Outlook	Glasbac	Directional
I	Outlook	Cushion	Directional
J	Rococo	Glasbac	Directional
K	Stitched Up	Glasbac	Directional
L	Suits you	Cushion	Directional
M	Syncopations	Glasbac	Directional
N	Syncopations	Cushion	Directional
O	The Loop	Glasbac	Directional
P	The Loop	Cushion	Directional
Q	Yin Yang	Glasbac	Directional
R	Yin Yang	Cushion	Directional
S	Broadloom wool	Hessian	Directional

Table 4 Study Two - details of floor coverings tested with health care equipment

	Carpet	Backing	Installation method
1	Alliteration	Glasbac	Directional
2	Asana	Glasbac	Random
3	Bertola	Glasbac	Directional
4	Equilbrium II	Glasbac	Directional
5	Flow	Glasbac	Directional
6	Freestyle	Glasbac	Directional
7	Fusion	Glasbac	Quarter turn
8	Llano	Glasbac	Directional
9	Llano	Glasbac	Quarter turn
10	Longitude	Glasbac	Quarter Turn
11	Muse	Glasbac	Ashlar
12	Nubian	Glasbac	Quarter turn
13	Platform	Glasbac	Directional
14	Prairie grass	Glasbac	Directional
15	Prairie grass	Glasbac	Quarter turn
16	Raw	Glasbac	Random
17	San Rocco	Glasbac	Directional
18	Solace	Glasbac	Directional
19	Striation	Glasbac	Directional
20	Tempest	Glasbac	Directional
21	Urban retreat 101	Glasbac	Quarter turn
22	Urban retreat 101	Glasbac	Random
23	Urban retreat 201	Glasbac	Quarter turn
24	Urban retreat 202	Glasbac	Directional
25	Urban retreat 203	Glasbac	Quarter turn
26	Urban retreat 302	Glasbac	Quarter turn
27	Urban retreat 303	Glasbac	Directional
28	Vermont	Glasbac	Directional
29	Walk the plank	Glasbac	Directional

[END]