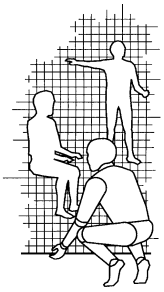
Mark Dohrmann and Partners Pty Ltd
Ergonomics Safety Risk Management



Forces required to move wheeled equipment on selected carpets

A report prepared for
Interface Pty Ltd
Asia Pacific Region

by

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Contents

Executive summary

This is a report on an independent scientific research project commissioned by Interface Pty Ltd and carried out by Mark Dohrmann and Partners Pty Ltd, consulting engineers and ergonomists.

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 to be installed in these settings, thereby assisting in ensuring that their legal obligations are met and that the people whose work includes the movement of equipment across carpet will not be exposed to undue risk.

Six items of wheeled equipment commonly used in health and aged care settings were used in the testing. These were a bed, a wheelchair, a mobile hoist, a lifting machine, a walker and a meal trolley. Five of each of the six items of equipment were tested in two separate test rounds. In each case, the tests examined initial push and pull force, with the wheels both aligned with the intended direction of movement, then unaligned, and for both sustained push and pull force.

In the first round of tests (August 2010), eighteen samples of carpet tiles and one broadloom carpet were provided and installed by Interface for the hospital equipment testing. For the second round of tests (March 2014), twenty-nine further samples of carpet tiles were provided and installed by Interface.

All installations used "TacTiles" on concrete flooring. All floor coverings were tested in opposing directions to control for potential variations in any uneven floor surface, or for any changes in resistance due to the direction of the fall of the pile.

Pull forces were measured using a calibrated, hand-held analogue force gauge, Model NK-500. All of the testing was carried out by a qualified and experienced ergonomist. Required push forces were assumed to be physically equivalent to pull forces.

The criterion 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[1] to 21 kg for initial force
- 6 kg to 12 kg for sustained force.

[1] The kg unit, which is a weight, not a force, is used throughout to assist lay appreciation of the forces involved. Force was measured in Newton (N), where 1 kg = 9.8 N.

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 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, every eight hours, or for a pull distance of 7.6 metres every five minutes.

The report compares the results for each carpet and each item of equipment with these criteria, and makes recommendations about the acceptable frequency and duration of pushing and pulling by a female working alone. It should be noted that many hospitals use tuggers or require two workers to move beds with patients in them.

Moving a bed consistently required the highest force.

The sustained bed movement force on all 17 of the carpets in Study One -the first round of tests (2010) - was 11 kg or less, and 12 kg or less for 17 of the 28 carpets in Study Two - the second round of tests (2014). The range recommended by Lawson and Potiki (1994) is 6 kg to 12 kg for sustained force. Bed movement forces on the other 12 carpets in the second round of tests exceeded 12 kg by only a small margin (typically about 5%).

The initial forces required to move the bed with the wheels aligned on any of the carpets tested in either round of tests did not exceed the limits set by Lawson and Potiki (1994).

The forces with the wheels initially set at right angles to the direction of travel were variable, but were generally higher than the initial forces (with the wheels aligned). This indicates that caution should be exercised when first moving an item of heavy equipment, and particularly when manoeuvring such equipment in confined spaces.

Mobile hoists have particular characteristics, such as small wheels and a mechanical disadvantage when turning, which makes their use in confined spaces difficult. A design alternative being used in some new facilities is to fit ceiling-mounted, track-based hoists over the beds of highly dependent residents, so that commode chairs can be used for transferring dependent residents between bed and an ensuite or a day chair.

There are a number of factors other than movement forces for wheeled equipment that need to be considered when choosing floor coverings in various parts of health and aged care facilities. These include cost of installation; 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 (home-like environment). Aged care facilities are both a person’s home as well as a workplace, and the needs and legal requirements of both ought to be fulfilled, as far as possible.

Based on the measurements taken in this study, all of the carpeted surfaces allowed safe push and pull forces for the particular type of equipment tested, and for a simulated patient weight of 70 kg, 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.

Heavier gross weights will result in higher forces, which at some point may require risk control, such as using a powered tugger or requiring two people to push the bed. The testing also suggests that larger wheels generally reduce the resistance to pushing and pulling on carpeted surfaces, as would be expected.

Forces required to move wheeled equipment on selected Interface commercial carpets

1 Background

This is the report on a project commissioned by Interface and carried out by Mark Dohrmann and Partners Pty Ltd, engineers and ergonomists. The advice contained herein is based on the independent results and conclusions drawn from this project.

The aim of the project was to provide scientific evidence which demonstrates the effects of different types of carpet tiles 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 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 carpets carried out in 2010 (Study One), and then in 2014, on different carpets (Study Two).

2 Method

2.1 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 Table 1 below.

The 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. Wheel chair 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 Table 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	

2.2 Floor coverings tested

Study One

Eighteen samples of floor coverings were provided and installed by Interface for testing health and aged care equipment, and nineteen including a broadloom wool on hessian backing. All floor coverings were installed in a direct-stick installation method onto a flat concrete floor. All floor coverings were tested in two opposite directions, to control for any variation in floor slope or directional resistance of the carpet.

Details of all the floor coverings were provided by Interface and are set out in Table 3 below. Glasbac is a relatively firm backing material for carpet, compared to cushion back.

Study Two

Twenty-nine samples of floor carpet tiles were provided and installed by Interface for testing. All floor coverings were installed using “TacTiles” onto a flat concrete floor. Again, all floor coverings were tested in two opposite directions, to control for any variation in floor slope or directional resistance of the carpet.

Details of all the floor coverings were provided by Interface and are set out in Table 4 below.

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

2.3 Force measurements

Forces were measured in each study using a hand-held calibrated analogue force gauge (Model NK-500). 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 the kg unit is likely to be more familiar to most readers.

Measurements were made of the force required to pull each item of equipment. 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. 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, and also with the wheels set at right angles to the direction of travel. 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, and then the average of the three remaining readings was calculated. The final reading was the average of the three middle values in both directions.

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 below) 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 further referenced to sex; to the percentage of the target group who will be capable; 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.

2.4 Determining criteria for a maximum acceptable force

Lawson and Potiki (1994) 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.

One of the issues in relation to bed pushing or pulling is moving beds over long distances on carpet. The criterion used to assess whether this task is safe or not is the Tables of Acceptable Forces published by Snook and Ciriello (1991). Known generally as "the Snook Tables", these are a well-accepted guide in the field of occupational health and safety.

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).

When Snook first published his tables in 1978, he suggested that tasks should be within the maximum acceptable force for 75% of the working population, based on his task analysis of

a wide range of tasks, and correlating the task demands with injuries reported from each of those tasks. In accordance with Snook's research, we have used the maximum acceptable force of which 75% of the female population is capable. This corresponds to the capability level of over 90% of the male population.

Snook Table 7 provides maximum acceptable push forces for a range of female strengths, for various hand heights, push distances and push frequencies, for both initial and sustained forces. Table 9 provides maximum acceptable pull forces for the same criteria.

3 Results

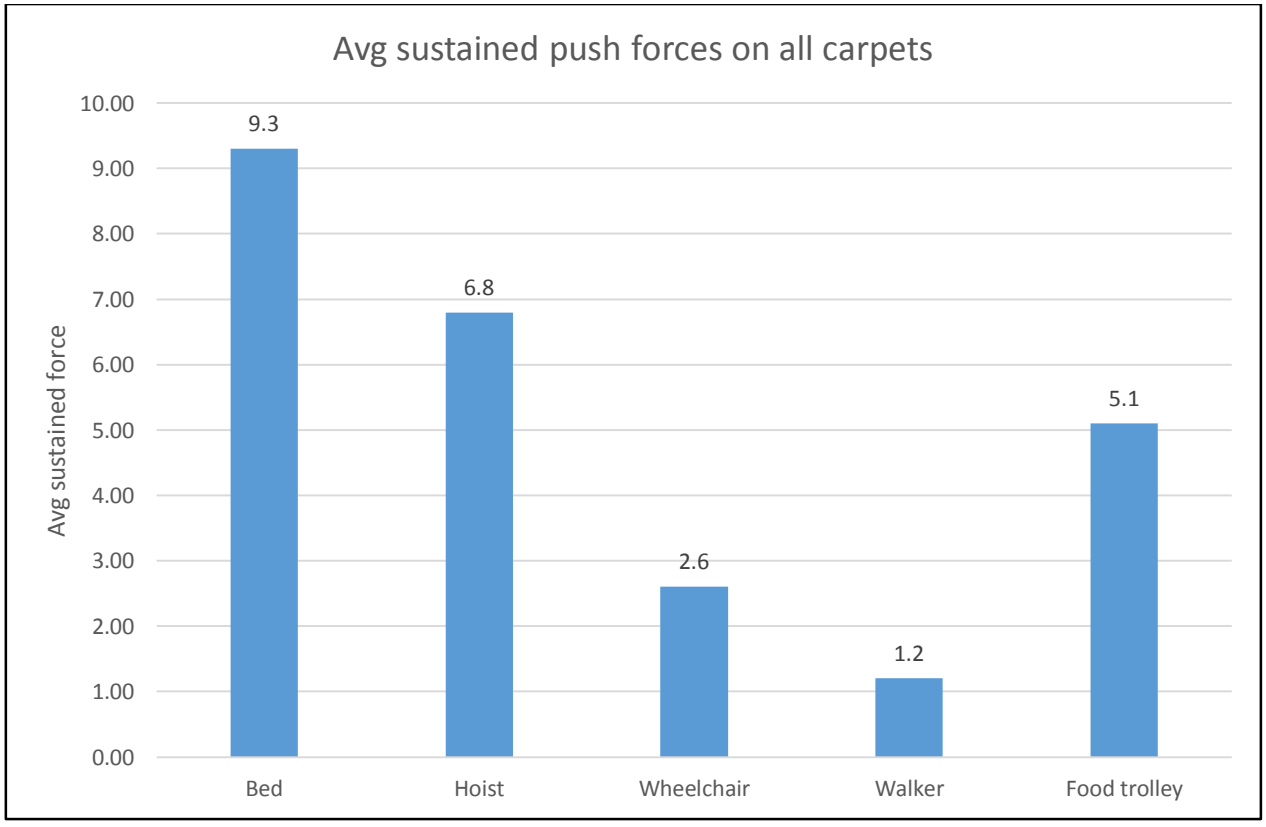
3.1 Sustained push or pull force results

Study One

The sustained push forces for each item of hospital equipment, averaged over all the floor coverings, are shown in Figure 1. 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 and food trolley were low, and so they were tested only on four of the carpets. Wheelchairs were also low-force, but were tested on all floor surfaces to provide information relevant to manual self-propulsion by the user.

Figure 1 Study One - average of sustained push forces for each item of equipment, averaged over all floor surfaces on which each item was tested.

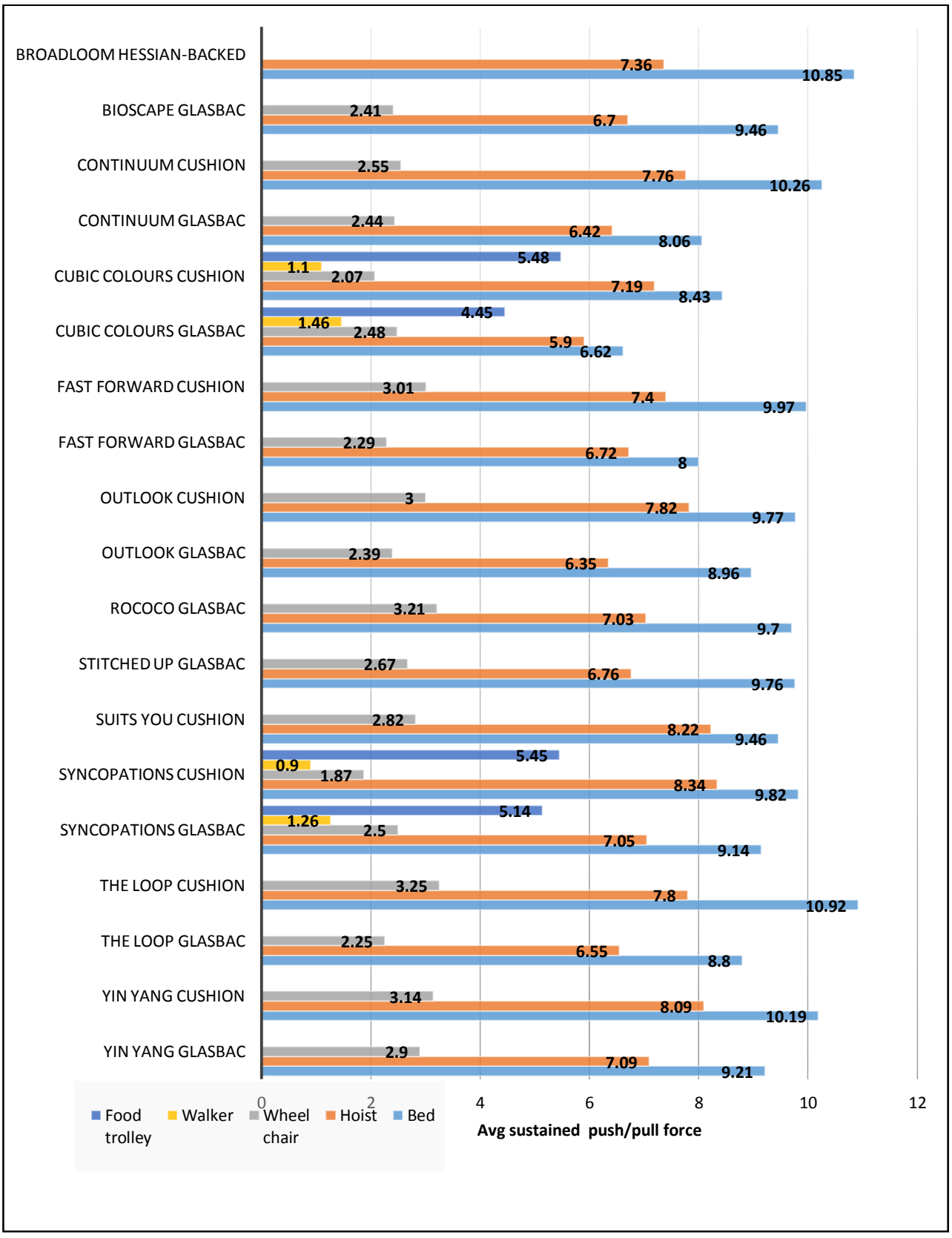


The sustained push forces required to keep the various items of equipment moving steadily on the various floor coverings in Study One are shown in Table 5, and illustrated graphically in a series of charts labelled Figure 2 and 3.

Table 5 Study One - sustained pull/push forces, in kg, on various floor coverings

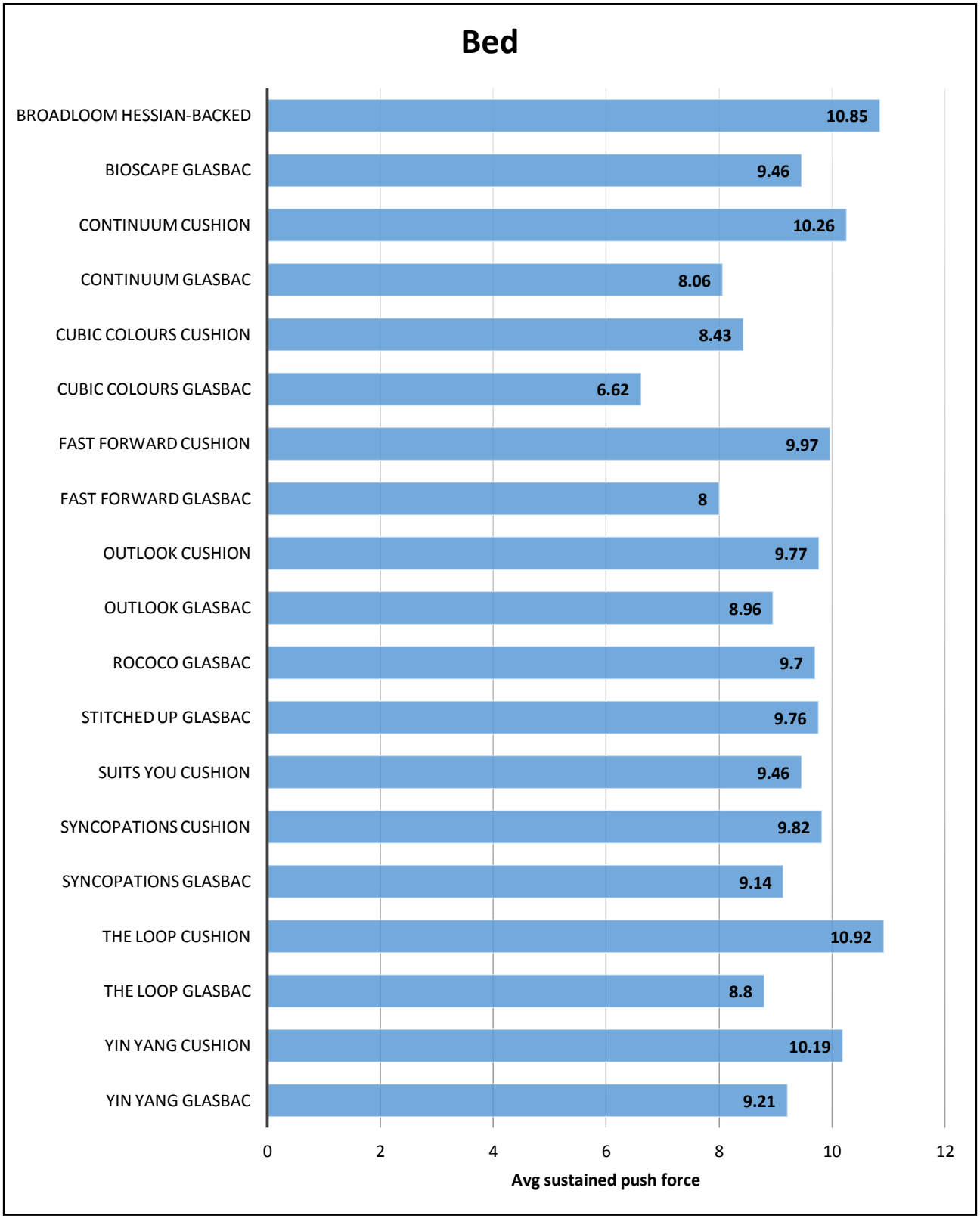
	Carpet	Bed	Hoist	Wheel chair	Walker	Food trolley
A	Bioscape Glasbac	9.46	6.7	2.41		
B	Continuum Glasbac	8.06	6.42	2.44		
C	Continuum Cushion	10.26	7.76	2.55		
D	Cubic Colours Glasbac	6.62	5.9	2.48	1.46	4.45
E	Cubic Colours Cushion	8.43	7.19	2.07	1.1	5.48
F	Fast forward Glasbac	8	6.72	2.29		
G	Fast forward Cushion	9.97	7.4	3.01		
H	Outlook Glasbac	8.96	6.35	2.39		
I	Outlook Cushion	9.77	7.82	3		
J	Rococo Glasbac	9.7	7.03	3.21		
K	Stitched Up Glasbac	9.76	6.76	2.67		
L	Suits you Cushion	9.46	8.22	2.82		
M	Syncopations Glasbac	9.14	7.05	2.5	1.26	5.14
N	Syncopations Cushion	9.82	8.34	1.87	0.9	5.45
O	The Loop Glasbac	8.8	6.55	2.25		
P	The Loop Cushion	10.92	7.8	3.25		
Q	Yin Yang Glasbac	9.21	7.09	2.9		
R	Yin Yang Cushion	10.19	8.09	3.14		
S	Broadloom Hessian-backed	10.85	7.36			

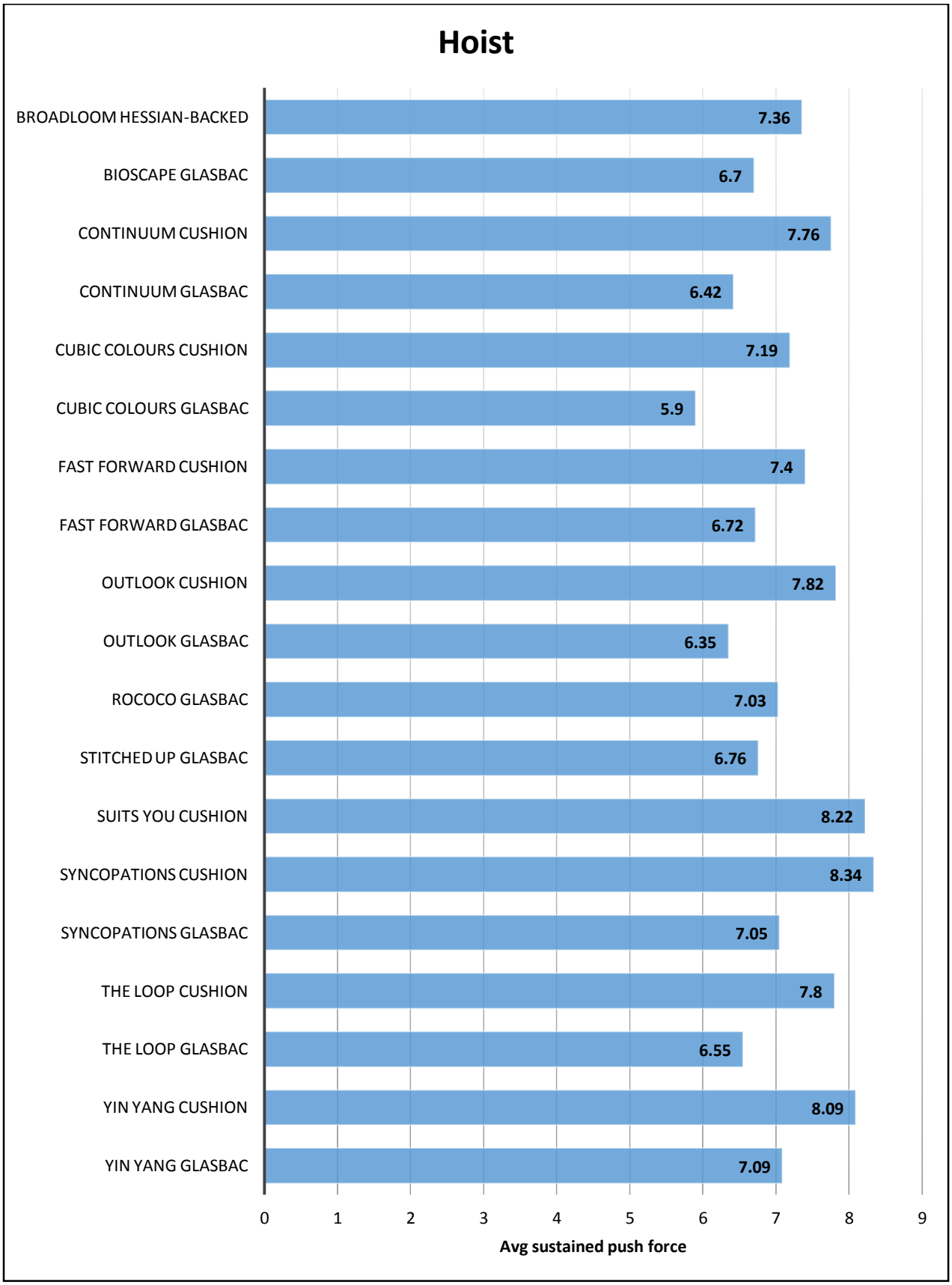
Figure 2 **Study One - chart of sustained pull/push forces on various floor coverings.**

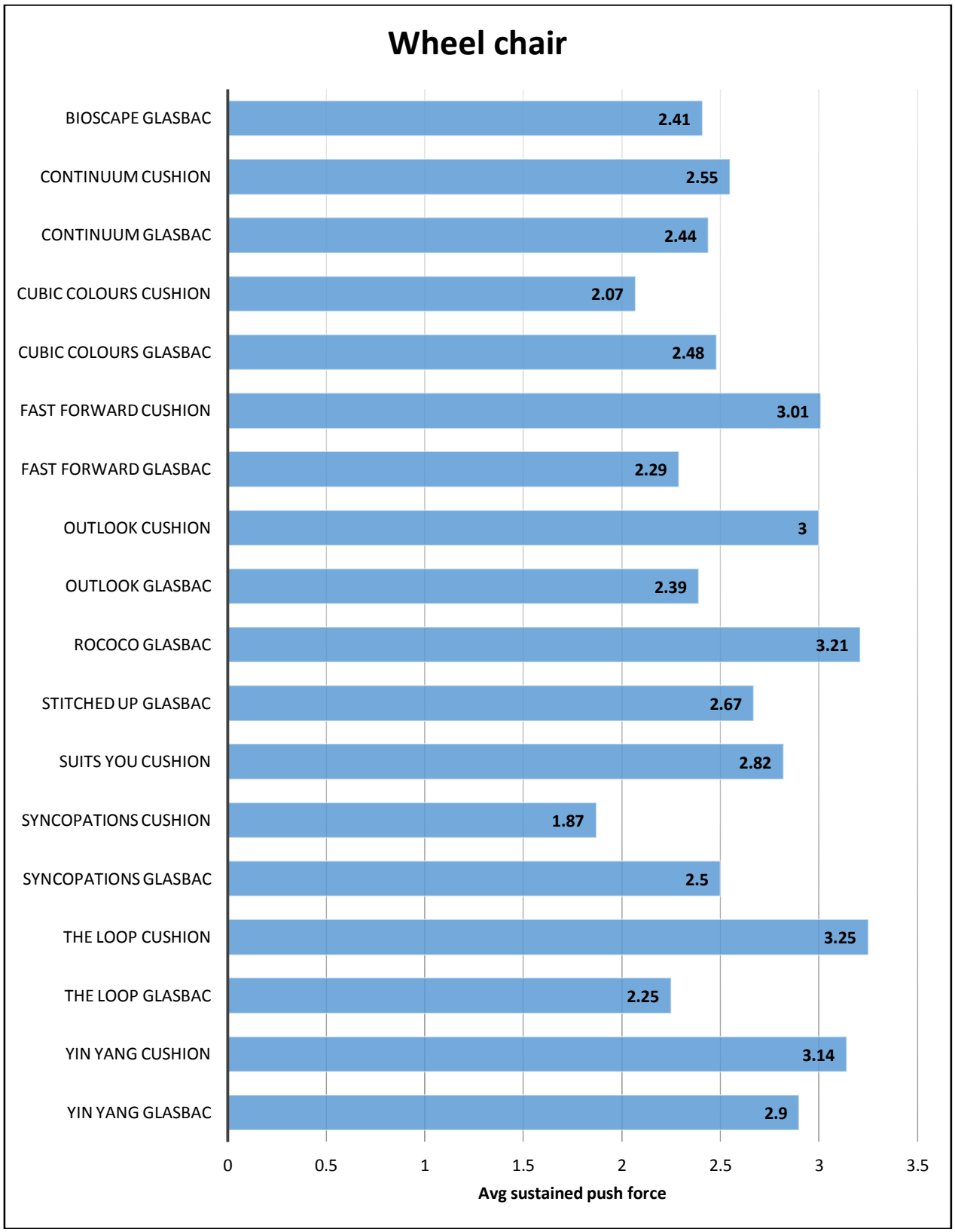


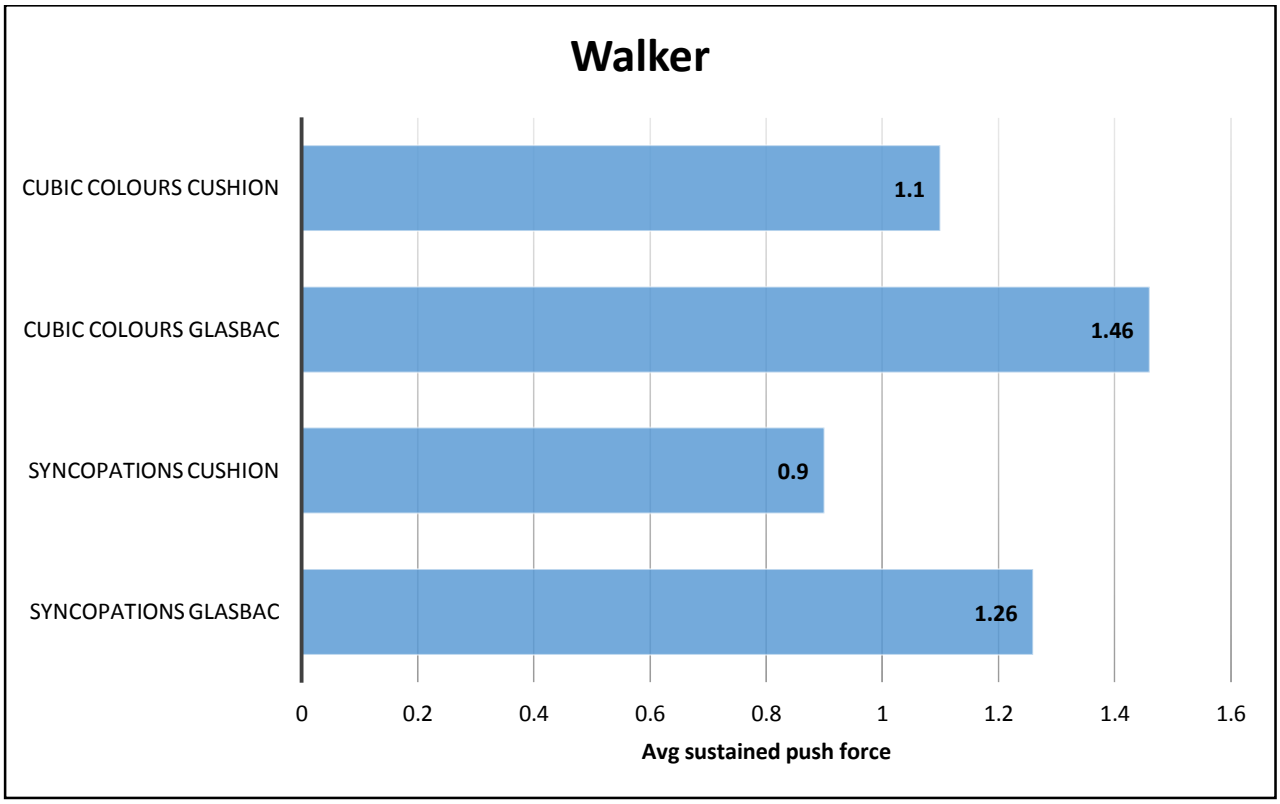
The sustained push forces to keep the typical bed in motion on the various floor coverings fall within the range 6 to 11 kg.

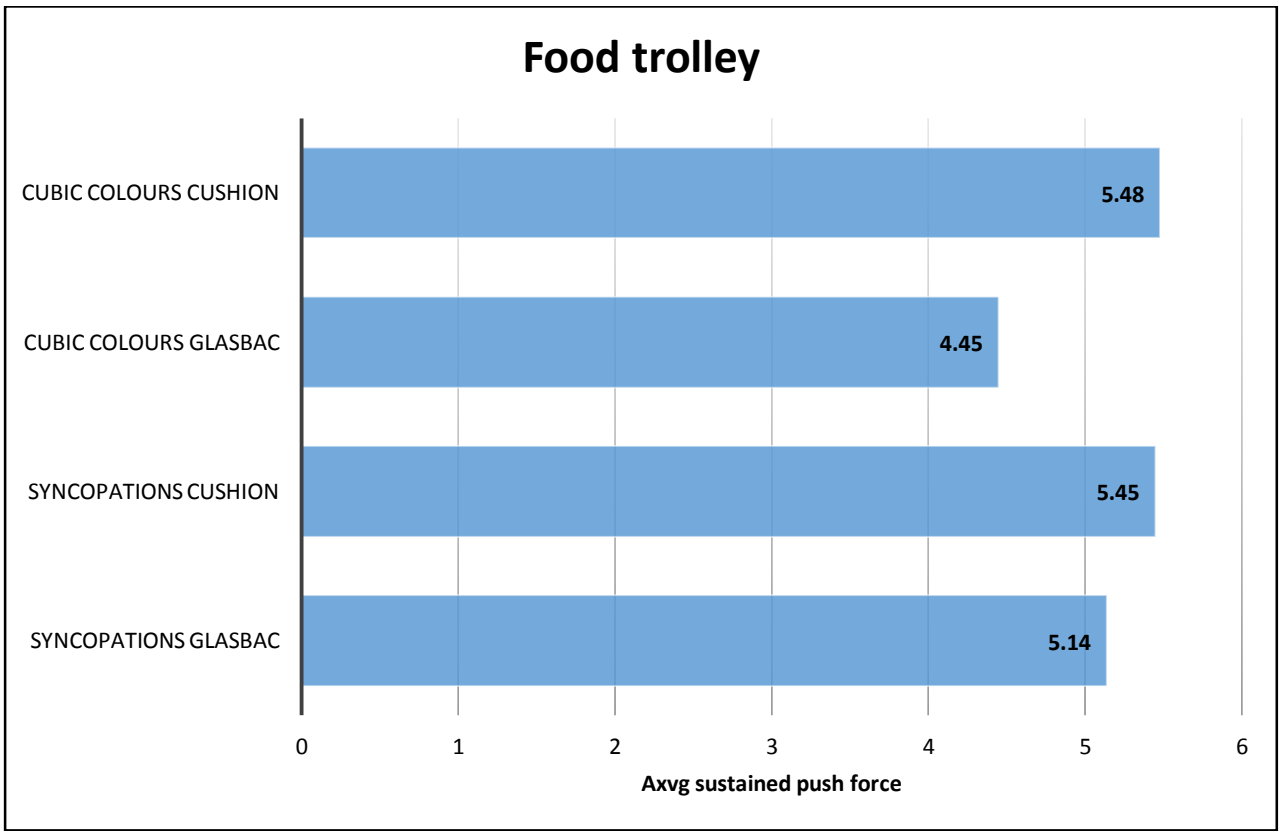
Figure 3 Study One: chart series of sustained push force on various floor coverings for individual items of equipment.




Hoist
BROADLOOM HESSIAN-BACKED
7.36
BIOSCAPE GLASBAC
6.7
CONTINUUM CUSHION
7.76
CONTINUUM GLASBAC
6.42
CUBIC COLOURS CUSHION
7.19
CUBIC COLOURS GLASBAC
5.9
FAST FORWARD CUSHION
7.4
FAST FORWARD GLASBAC
6.72
OUTLOOK CUSHION
7.82
OUTLOOK GLASBAC
6.35
ROCOCO GLASBAC
7.03
STITCHED UP GLASBAC
6.76
SUITS YOU CUSHION
8.22
SYNCOPATIONS CUSHION
8.34
SYNCOPATIONS GLASBAC
7.05
THE LOOP CUSHION
7.8
THE LOOP GLASBAC
6.55
YIN YANG CUSHION
8.09
YIN YANG GLASBAC
7.09
0
1
2
3
4
5
6
7
8
9
Avg sustained push force


Wheel chair
BIOSCAPE GLASBAC
2.41
CONTINUUM CUSHION
2.55
CONTINUUM GLASBAC
2.44
CUBIC COLOURS CUSHION
2.07
CUBIC COLOURS GLASBAC
2.48
FAST FORWARD CUSHION
3.01
FAST FORWARD GLASBAC
2.29
OUTLOOK CUSHION
3
OUTLOOK GLASBAC
2.39
ROCOCO GLASBAC
3.21
STITCHED UP GLASBAC
2.67
SUITS YOU CUSHION
2.82
SYNCOPATIONS CUSHION
1.87
SYNCOPATIONS GLASBAC
2.5
THE LOOP CUSHION
3.25
THE LOOP GLASBAC
2.25
YIN YANG CUSHION
3.14
YIN YANG GLASBAC
2.9
0
0.5
1
1.5
2
2.5
3
3.5
Avg sustained push force

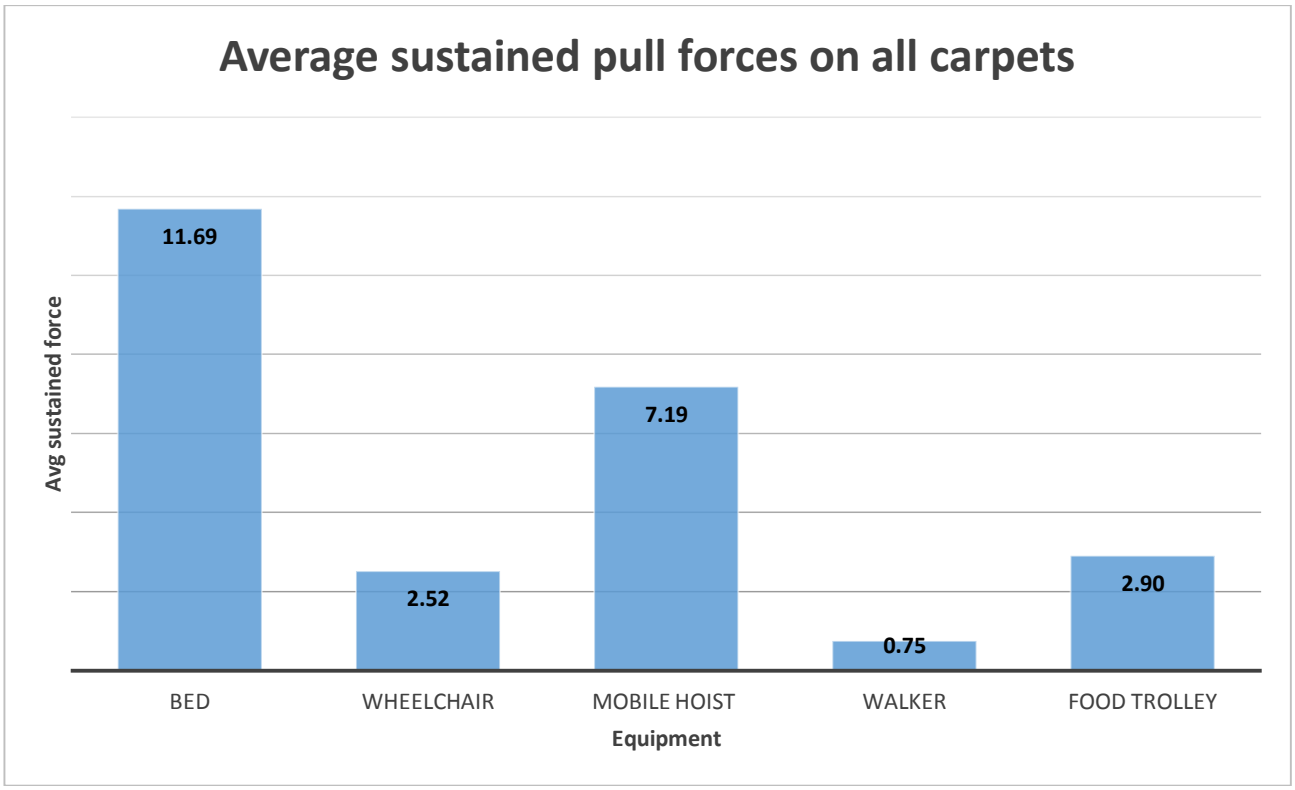

Walker
CUBIC COLOURS CUSHION
CUBIC COLOURS GLASBAC
SYNCOPATIONS CUSHION
SYNCOPATIONS GLASBAC
1.1
1.46
0.9
1.26
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Avg sustained push force


Food trolley
CUBIC COLOURS CUSHION
CUBIC COLOURS GLASBAC
SYNCOPATIONS CUSHION
SYNCOPATIONS GLASBAC
5.48
4.45
5.45
5.14
0
1
2
3
4
5
6
Axvg sustained push force

Study Two

The sustained pull forces for each item of hospital equipment, averaged over all the floor coverings, are shown in Figure 4. The bed was hardest to pull, followed by the mobile hoist. The other equipment was again easier to pull because of larger diameter wheels and/or a lighter load.

Figure 4 **Study Two - average of sustained pull forces for each item of equipment, averaged over all floor surfaces on which each item was tested.**

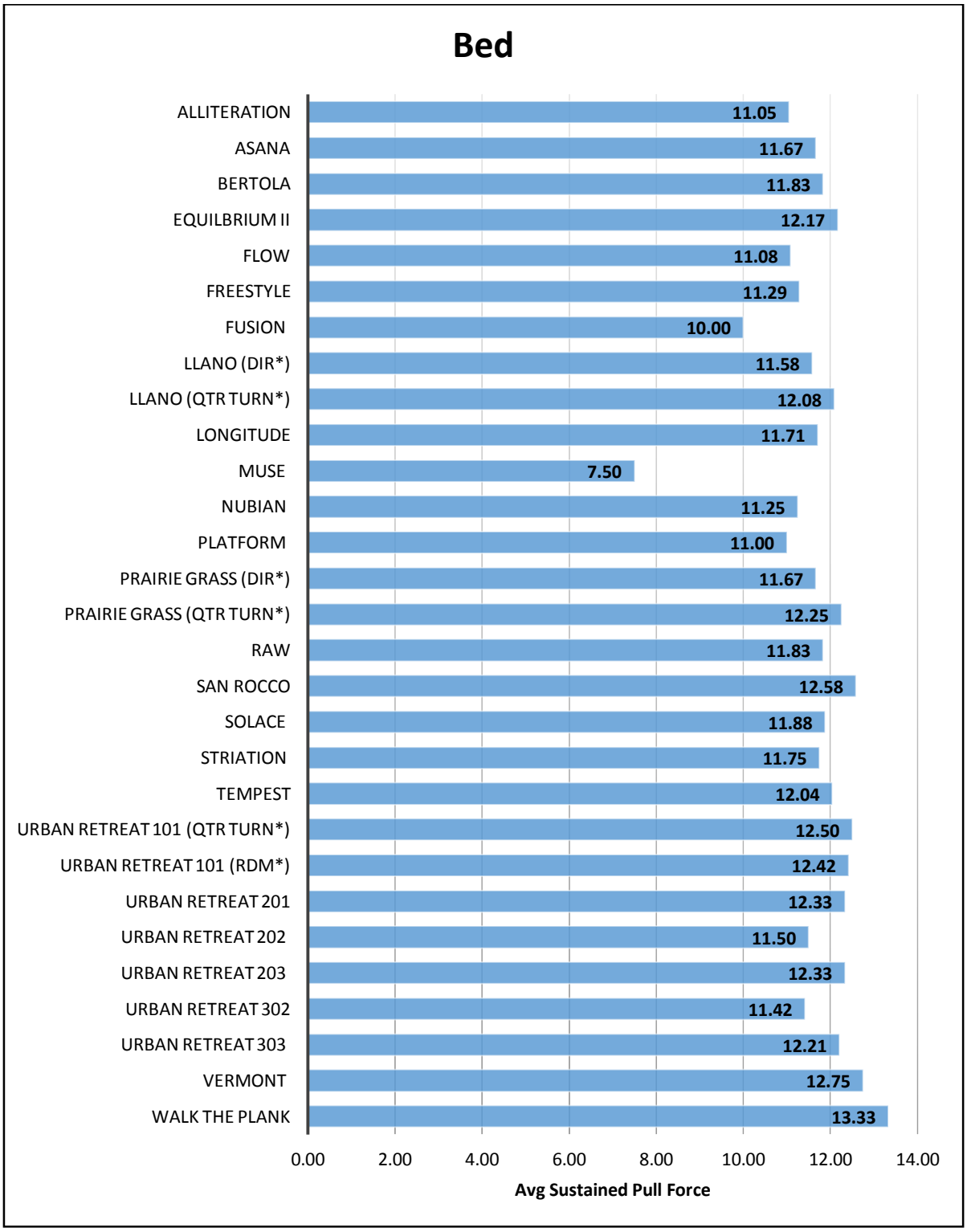


The individual sustained pull forces required to keep the various items of equipment moving steadily on the various floor coverings are shown in Table 6, and are illustrated graphically in a series of charts labelled Figure 5, following Table 6.

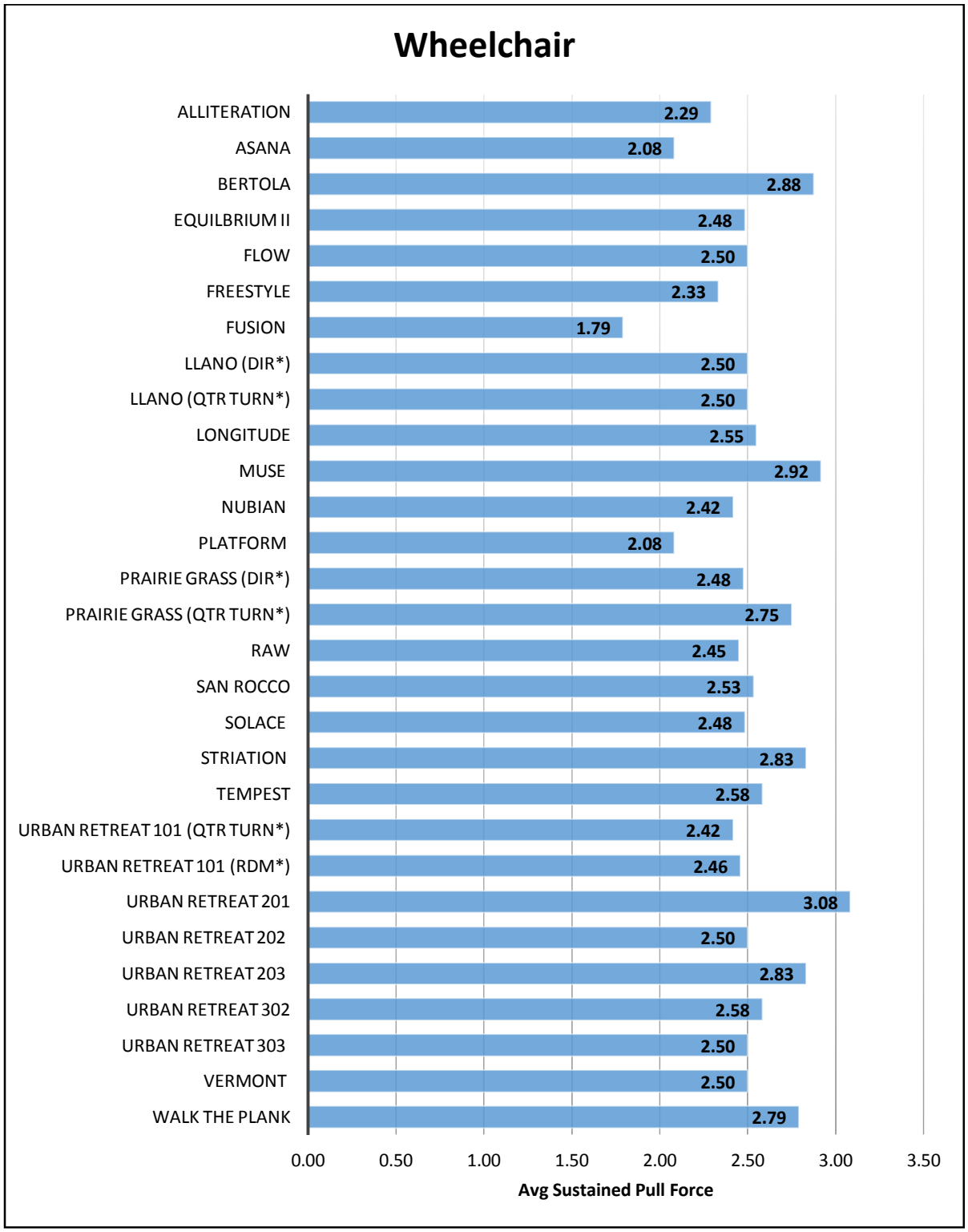
Table 6 Study Two - sustained pull forces, in kg, on the various floor coverings

	Carpet	Installation method	Bed	Wheel chair	Mobile hoist	Walker	Food trolley
1	Alliteration	Directional	11.05	2.29	6.47	0.60	3.33
2	Asana	Random	11.67	2.08	6.70	0.75	2.67
3	Bertola	Directional	11.83	2.88	7.57	1.08	3.38
4	Equilbrium II	Directional	12.17	2.48	7.47	0.63	2.50
5	Flow	Directional	11.08	2.50	6.33	0.96	2.50
6	Freestyle	Directional	11.29	2.33	6.93	0.79	2.67
7	Fusion	Quarter turn	10.00	1.79	7.31	0.54	1.88
8	Llano	Directional	11.58	2.50	7.53	0.75	2.67
9	Llano	Quarter turn	12.08	2.50	7.14	0.75	2.83
10	Longitude	Quarter Turn	11.71	2.55	7.31	0.62	2.57
11	Muse	Ashlar	7.50	2.92	7.40	1.00	3.50
12	Nubian	Quarter turn	11.25	2.42	6.92	0.83	2.50
13	Platform	Directional	11.00	2.08	6.75	0.79	2.50
14	Prairie grass	Directional	11.67	2.48	6.58	0.38	3.00
15	Prairie grass	Quarter turn	12.25	2.75	7.08	0.75	3.08
16	Raw	Random	11.83	2.45	7.47	0.75	3.00
17	San Rocco	Directional	12.58	2.53	7.33	0.88	2.81
18	Solace	Directional	11.88	2.48	6.63	0.75	2.57
19	Striation	Directional	11.75	2.83	7.25	0.75	2.83
20	Tempest	Directional	12.04	2.58	7.45	0.48	3.29
21	Urban retreat 101	Quarter turn	12.50	2.42	7.75	1.13	3.25
22	Urban retreat 101	Random	12.42	2.46	8.50	0.75	3.25
23	Urban retreat 201	Quarter turn	12.33	3.08	7.52	0.75	3.00
24	Urban retreat 202	Directional	11.50	2.50	7.08	0.75	3.00
25	Urban retreat 203	Quarter turn	12.33	2.83	7.38	0.67	3.50
26	Urban retreat 302	Quarter turn	11.42	2.58	6.67	0.75	2.92
27	Urban retreat 303	Directional	12.21	2.50	6.92	0.75	2.83
28	Vermont	Directional	12.75	2.50	7.45	0.67	3.08
29	Walk the plank	Directional	13.33	2.79	7.53	0.75	3.25

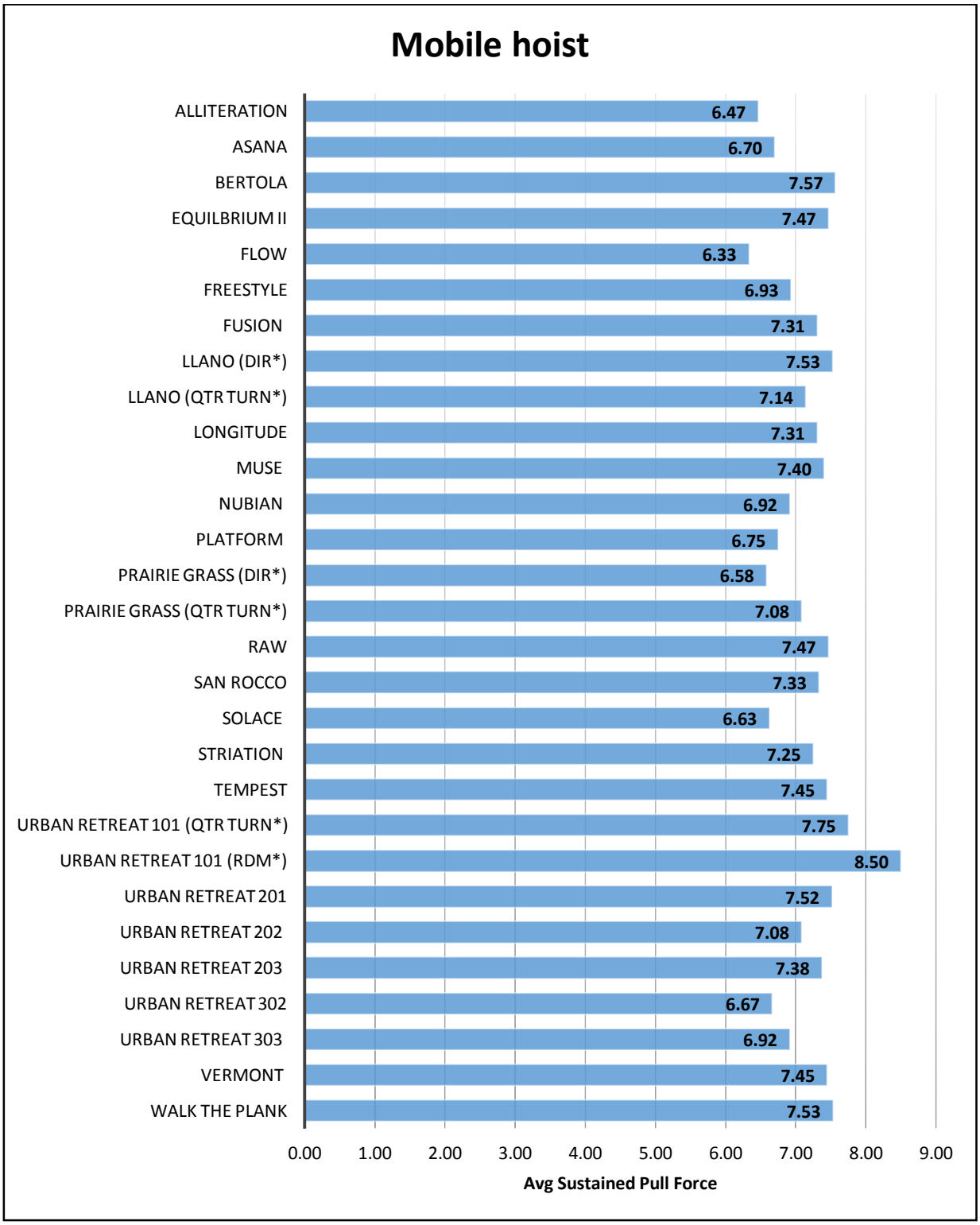
Figure 5 Study Two – chart series of sustained pull force on various floor covering for individual items of equipment.



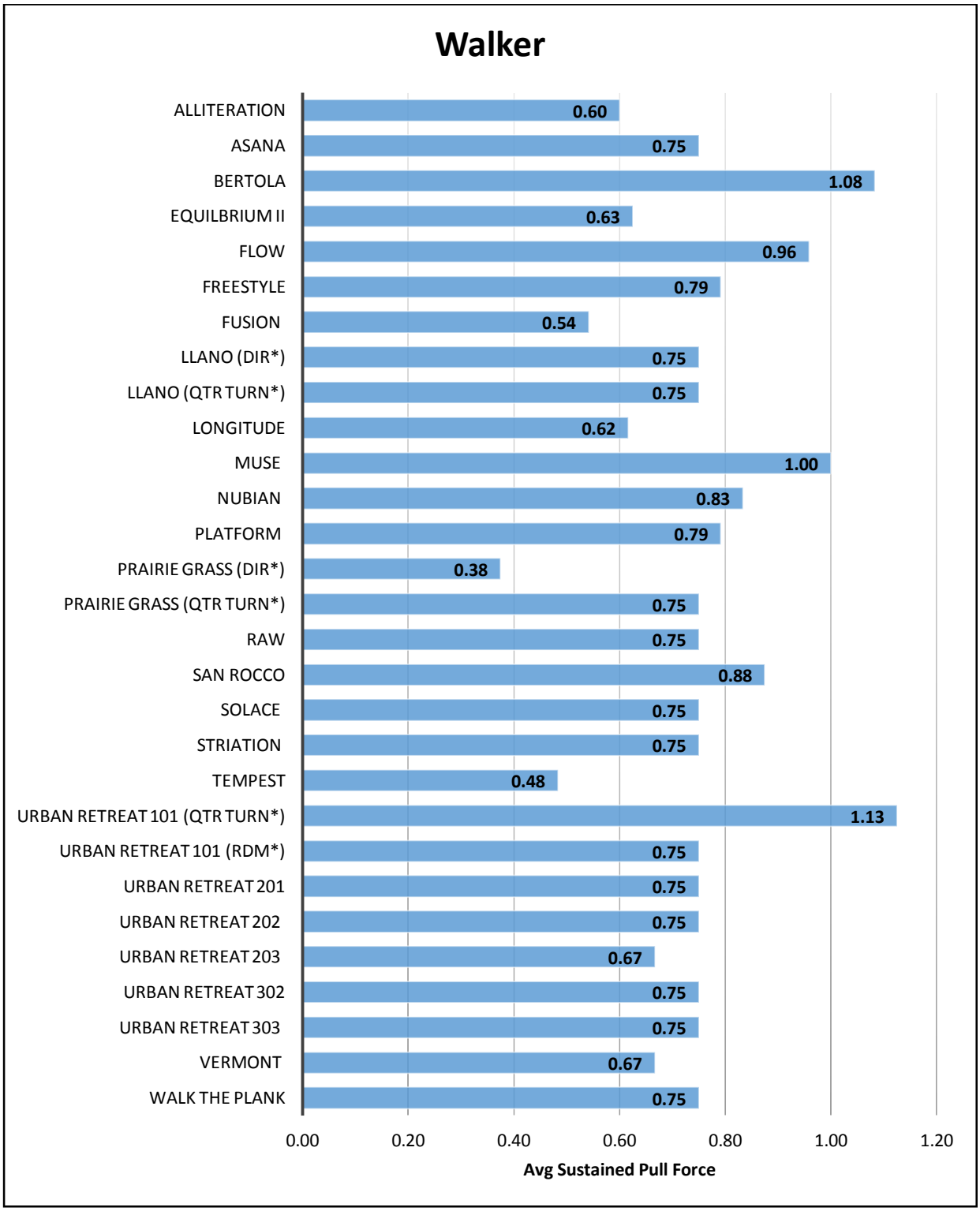
(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



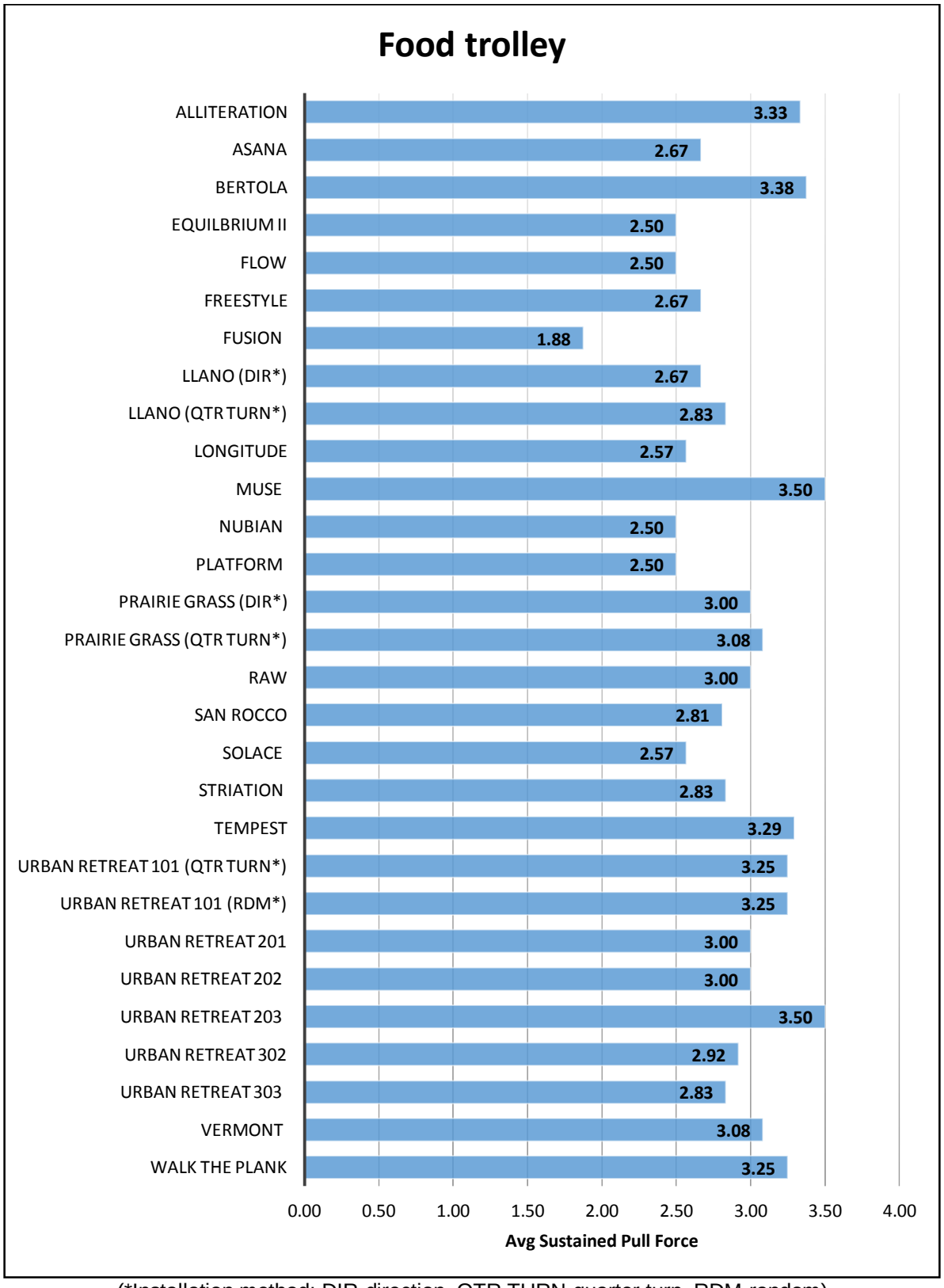
(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)

3.2 Comparison of force needed with maximum acceptable sustained push or pull forces

Study One

The sustained bed 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.

The maximum force measured for pushing a patient lifting machine on any of the surfaces was 8.3 kg. This is within the maximum force acceptable to 75% of the female working population for a distance of 45.7 metres once per 30 minutes, or for a distance of 15.2 metres once per minute. All of the Glasbac carpets required forces below 7.1 kg, which corresponds to safe pushing over 45.7 metres once every two minutes.

The forces to push the food trolley and the wheelchair were all below 6 kg. This is within the capability of 75% of the female working population for a 61 metre push every 2 minutes, or for a 15.2 metre push once per 25 seconds. This covers most work situations that are likely to arise.

Study Two

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 twelve carpets that exceeded 12 kg for the sustained pull force, by a small margin.

These were:

- Prairie Grass - Installed Quarter Turn
- Equilibrium - Installed Directional
- Tempest - Installed Directional
- San Rocco - Installed Directional
- Urban Retreat 101 - Installed Quarter Turn
- Urban Retreat 101 - Installed Random
- Urban Retreat 201 - Installed Directional
- Urban Retreat 203 - Installed Quarter Turn
- Urban Retreat 303 - Installed Directional
- Vermont - Installed Directional
- Walk the Plank - Installed Directional
- Llano - Installed Quarter Turn

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 indicates that -

- *A sustained push* force of 8.5 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 of 8.5 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 4 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 4 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 wheelchair indicates that -

- *A sustained push* force of 4 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 4 kg for the wheelchair (which is unlikely to be performed) 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.

3.3 Initial force results – wheels aligned

Study One

The initial push forces required to get the various items of equipment moving on the various floor coverings, starting with the wheels aligned, are shown in Table 7, and are illustrated graphically in Figures 6 and 7.

Table 7 **Study One - initial push forces, kg, on various carpets, wheels aligned**
Please note that broadloom hessian carpet was not tested

	Carpet	Bed	Hoist	Wheel chair	Walker	Food trolley
A	Bioscape Glasbac	17.34	10.02	4.06		
B	Continuum Glasbac	16.79	9.8	3.94		
C	Continuum Cushion	17.22	10.86	4.62		
D	Cubic Colours Glasbac	15.48	8.97	3.62	2.42	6.74
E	Cubic Colours Cushion	15.48	10.53	3.75	1.8	7.86
F	Fast forward Glasbac	16.14	10.04	3.99		
G	Fast forward Cushion	18.03	10.35	4.12		
H	Outlook Glasbac	16.45	9.5	3.92		
I	Outlook Cushion	16.98	10.62	4.71		
J	Rococo Glasbac	17.72	10.41	4.44		
K	Stitched Up Glasbac	16.11	10.07	3.91		
L	Suits you Cushion	16.75	11.12	4.61		
M	Syncopations Glasbac	18.02	10.61	4.09	2.35	8.69
N	Syncopations Cushion	18.22	11.46	3.86	1.89	7.75
O	The Loop Glasbac	16.6	9.27	3.59		
P	The Loop Cushion	18.28	10.79	5.39		
Q	Yin Yang Glasbac	16.96	10.41	4.49		
R	Yin Yang Cushion	18.5	11.09	4.78		

Figure 6 Study One – initial pull/push forces on various floor coverings, wheels aligned, for different items of equipment.

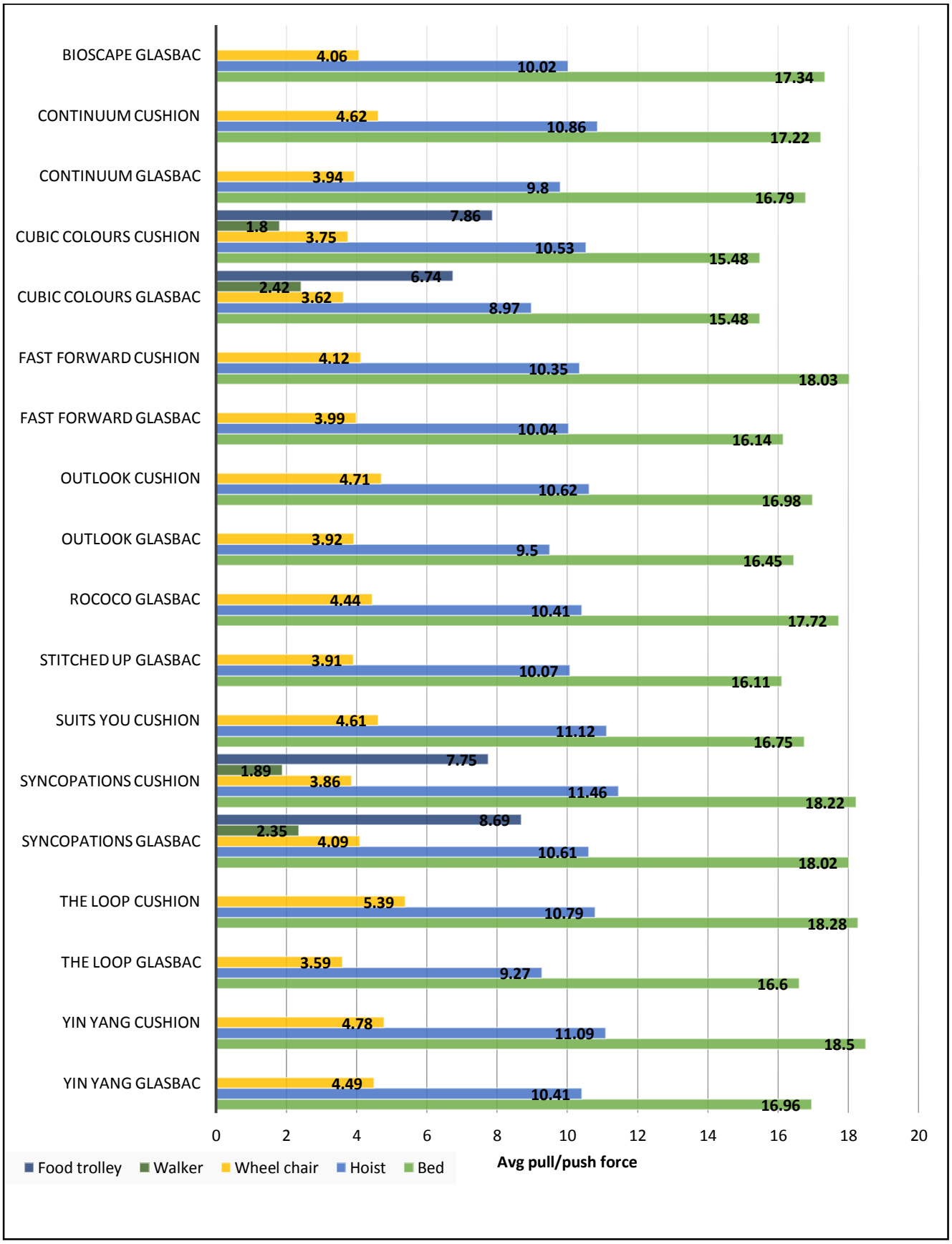
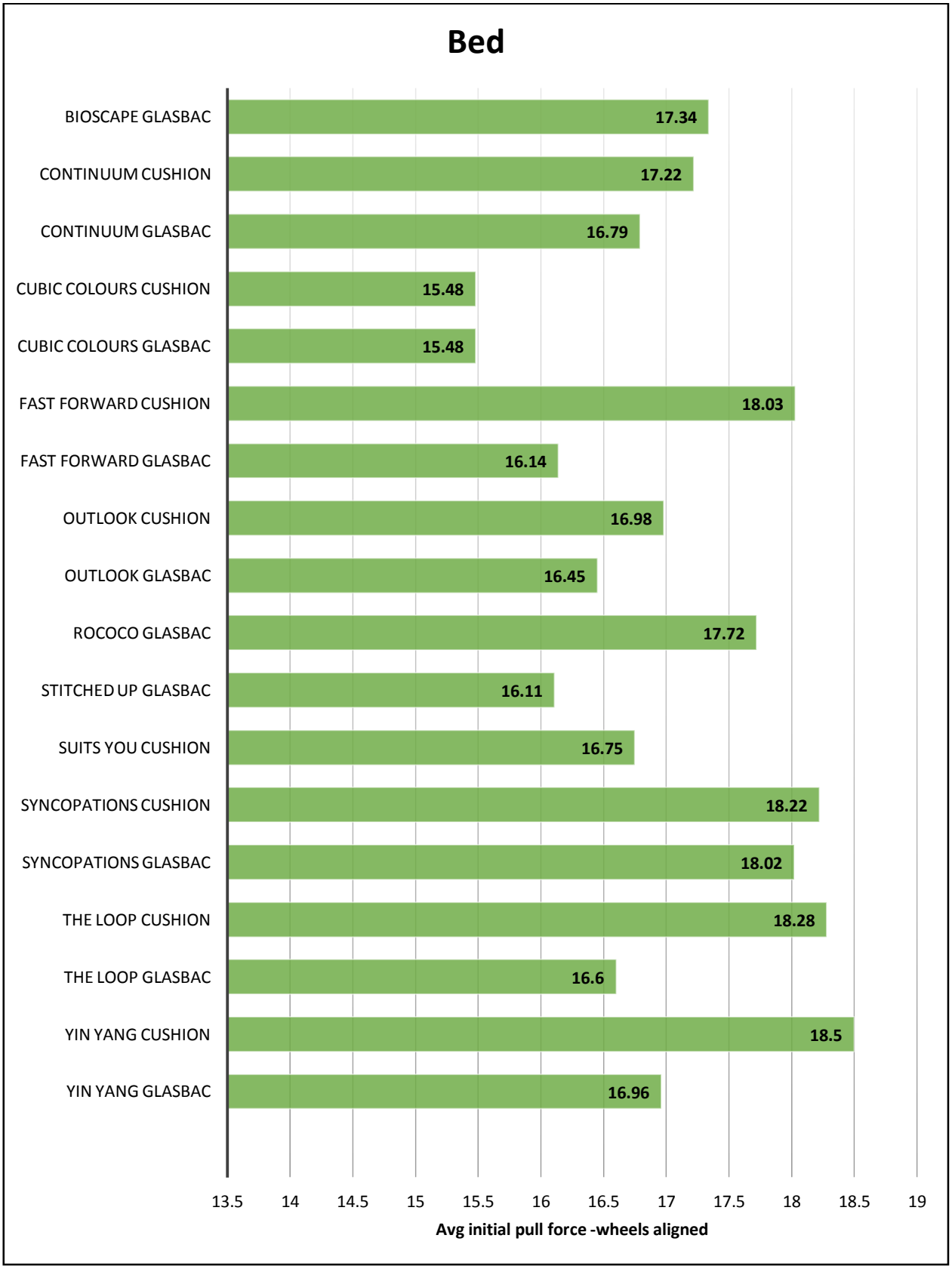
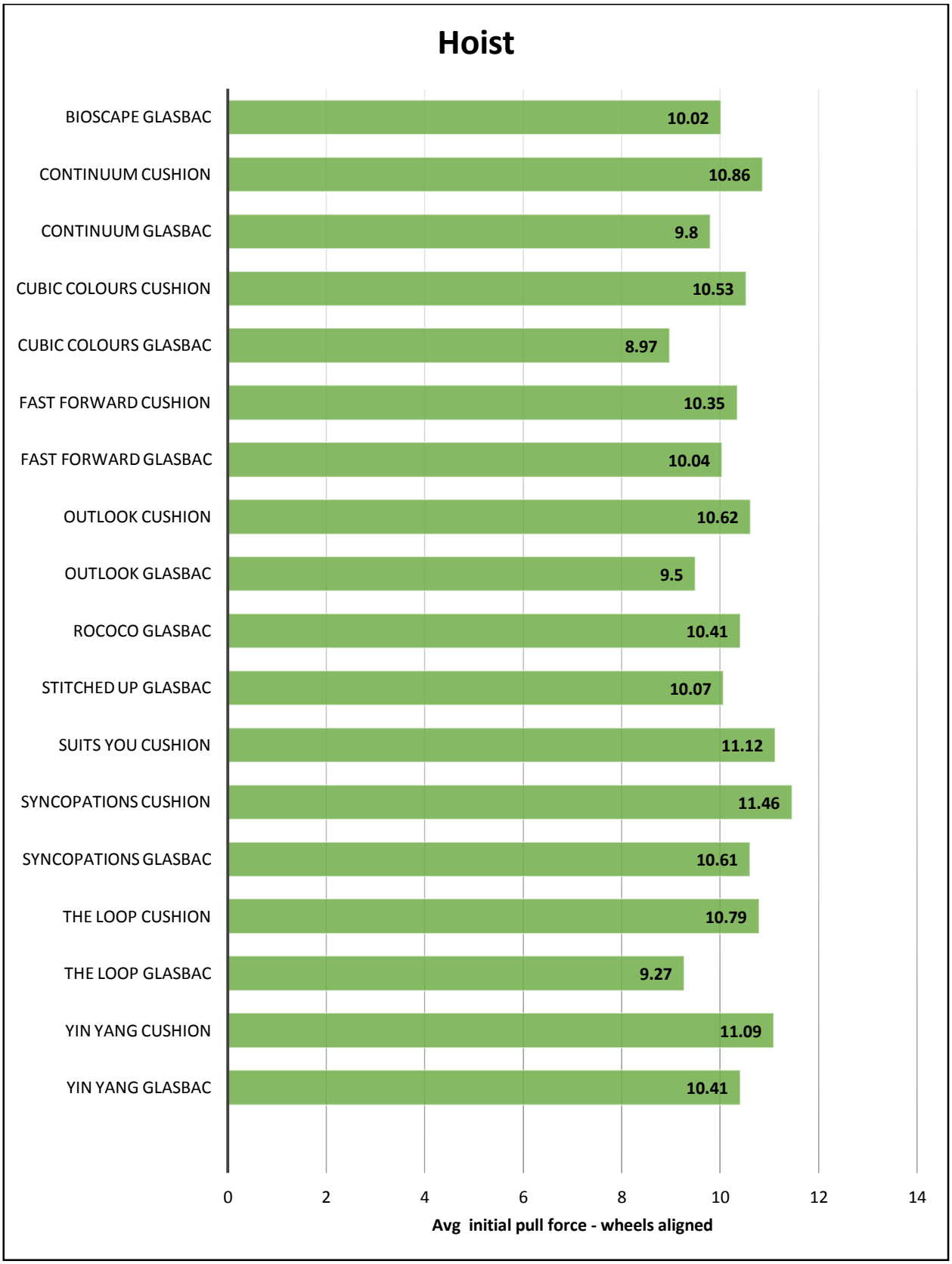
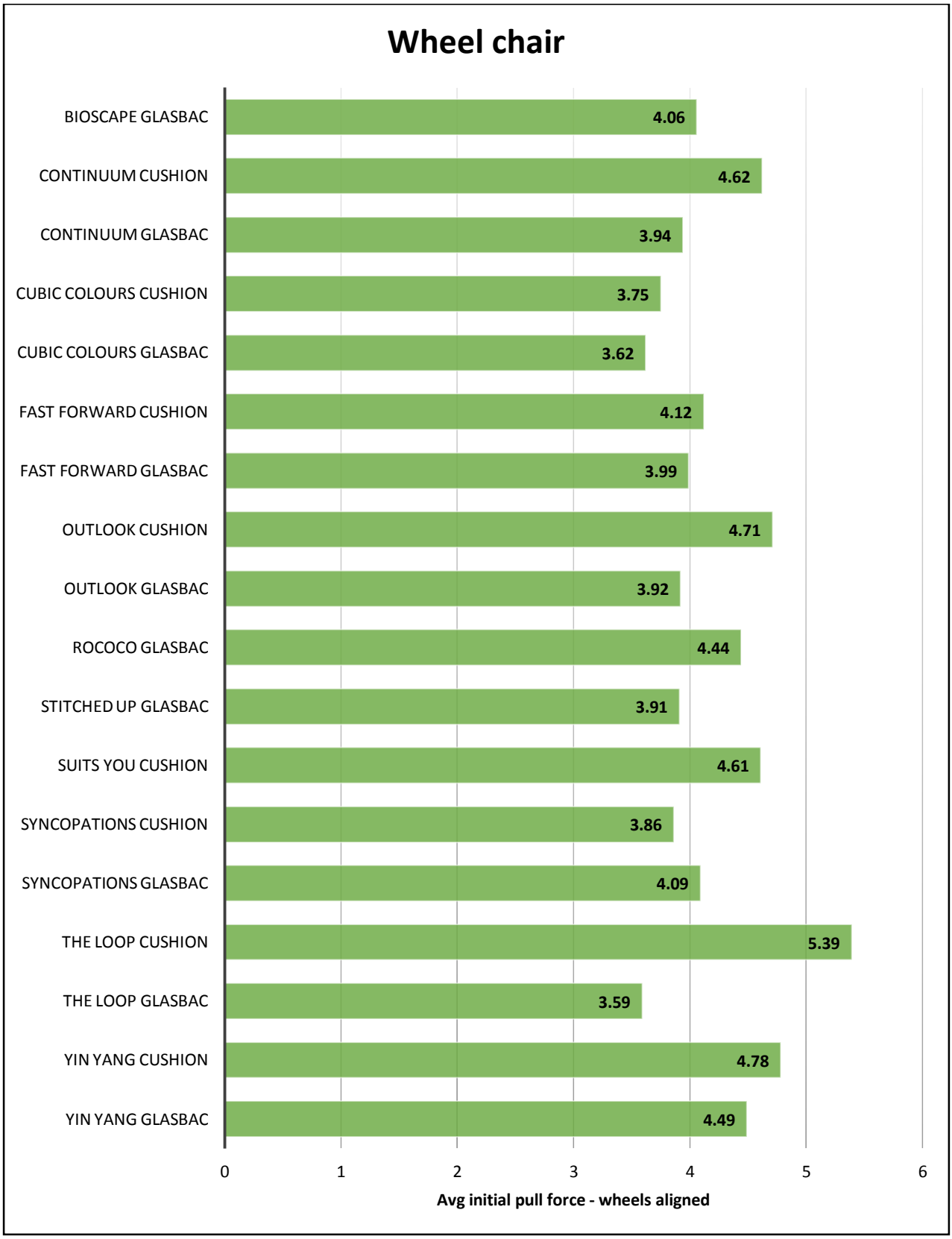
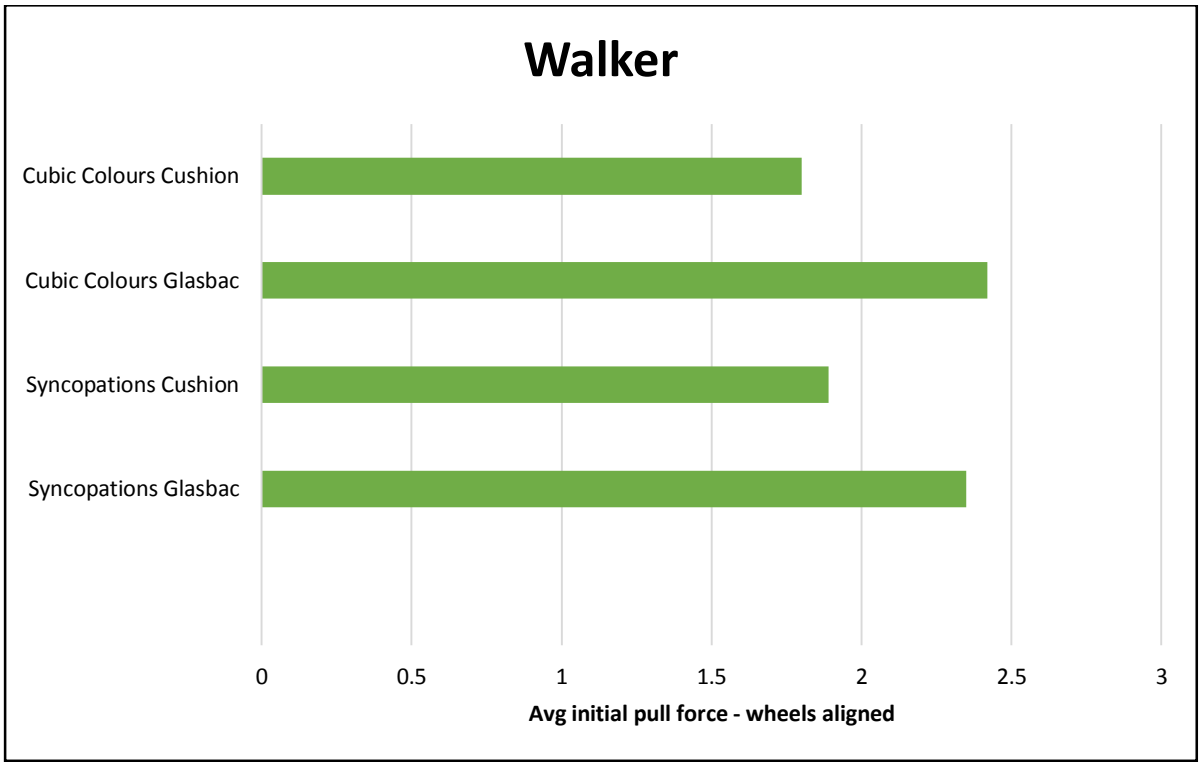


Figure 7 Study One – chart series of initial push forces on various floor coverings, wheels aligned, for individual items of equipment.




Hoist
BIOSCAPE GLASBAC
10.02
CONTINUUM CUSHION
10.86
CONTINUUM GLASBAC
9.8
CUBIC COLOURS CUSHION
10.53
CUBIC COLOURS GLASBAC
8.97
FAST FORWARD CUSHION
10.35
FAST FORWARD GLASBAC
10.04
OUTLOOK CUSHION
10.62
OUTLOOK GLASBAC
9.5
ROCOCO GLASBAC
10.41
STITCHED UP GLASBAC
10.07
SUITS YOU CUSHION
11.12
SYNCOPATIONS CUSHION
11.46
SYNCOPATIONS GLASBAC
10.61
THE LOOP CUSHION
10.79
THE LOOP GLASBAC
9.27
YIN YANG CUSHION
11.09
YIN YANG GLASBAC
10.41
0
2
4
6
8
10
12
14
Avg initial pull force - wheels aligned


Wheel chair
BIOSCAPE GLASBAC
4.06
CONTINUUM CUSHION
4.62
CONTINUUM GLASBAC
3.94
CUBIC COLOURS CUSHION
3.75
CUBIC COLOURS GLASBAC
3.62
FAST FORWARD CUSHION
4.12
FAST FORWARD GLASBAC
3.99
OUTLOOK CUSHION
4.71
OUTLOOK GLASBAC
3.92
ROCOCO GLASBAC
4.44
STITCHED UP GLASBAC
3.91
SUITS YOU CUSHION
4.61
SYNCOPATIONS CUSHION
3.86
SYNCOPATIONS GLASBAC
4.09
THE LOOP CUSHION
5.39
THE LOOP GLASBAC
3.59
YIN YANG CUSHION
4.78
YIN YANG GLASBAC
4.49
0
1
2
3
4
5
6
Avg initial pull force - wheels aligned

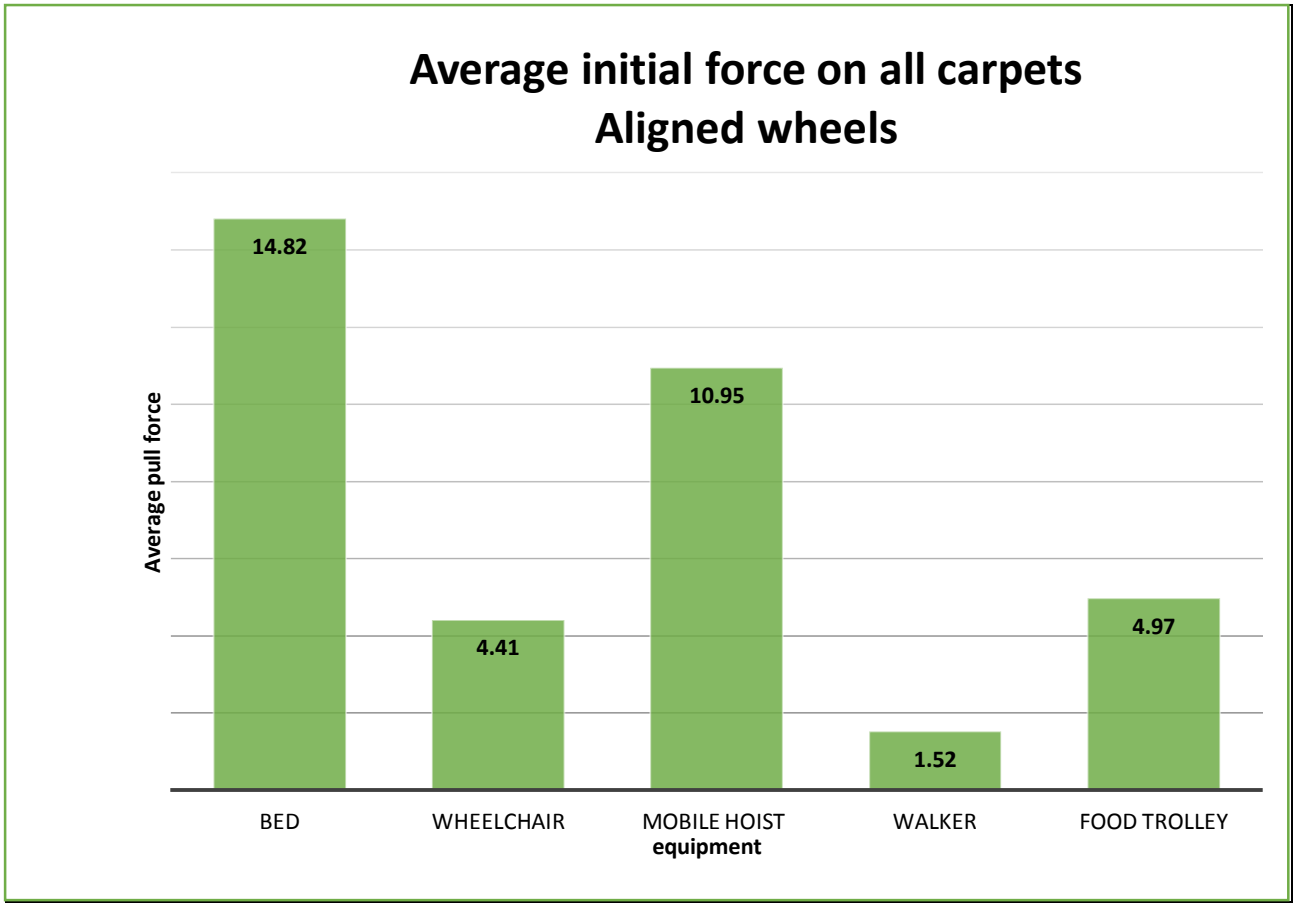

Walker
Cubic Colours Cushion
Cubic Colours Glasbac
Syncopations Cushion
Syncopations Glasbac
0
0.5
1
1.5
2
2.5
3
Avg initial pull force - wheels aligned


Food trolley
CUBIC COLOURS CUSHION
7.86
CUBIC COLOURS GLASBAC
6.74
SYNCOPATIONS CUSHION
7.75
SYNCOPATIONS GLASBAC
8.69
0
1
2
3
4
5
6
7
8
9
10
Avg initial pull force - wheels aligned

Study Two

The initial forces for each item of hospital 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 mobile hoist. The other equipment was again easier to move because of larger diameter wheels and/or a lighter load.

Figure 8 Study One - initial pull forces – wheels aligned, kg, on various carpets

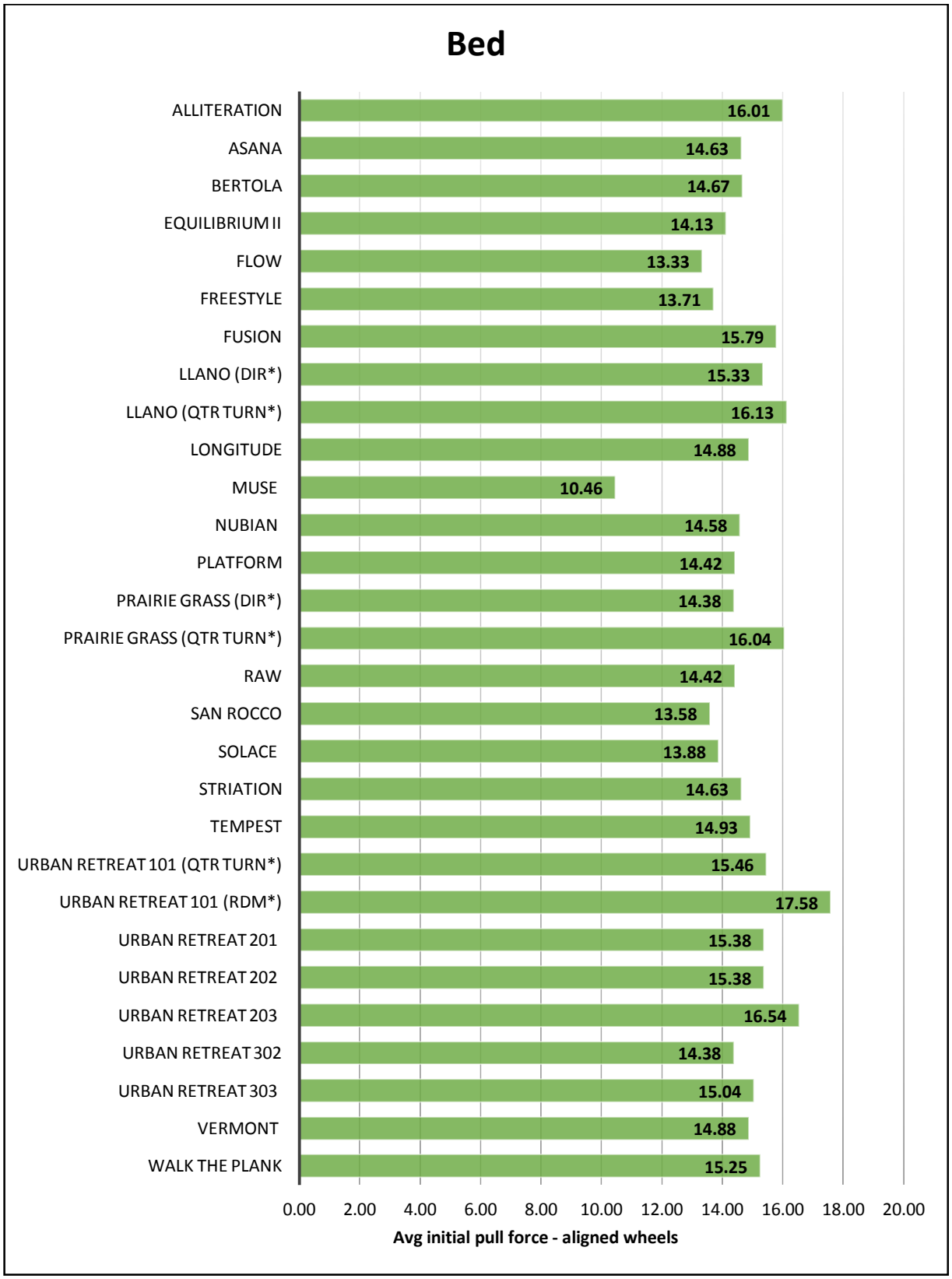


The individual initial pull forces required to get the various items of equipment moving on the various floor coverings, with the wheels aligned, are shown in Table 8, and are illustrated graphically in Figure 9.

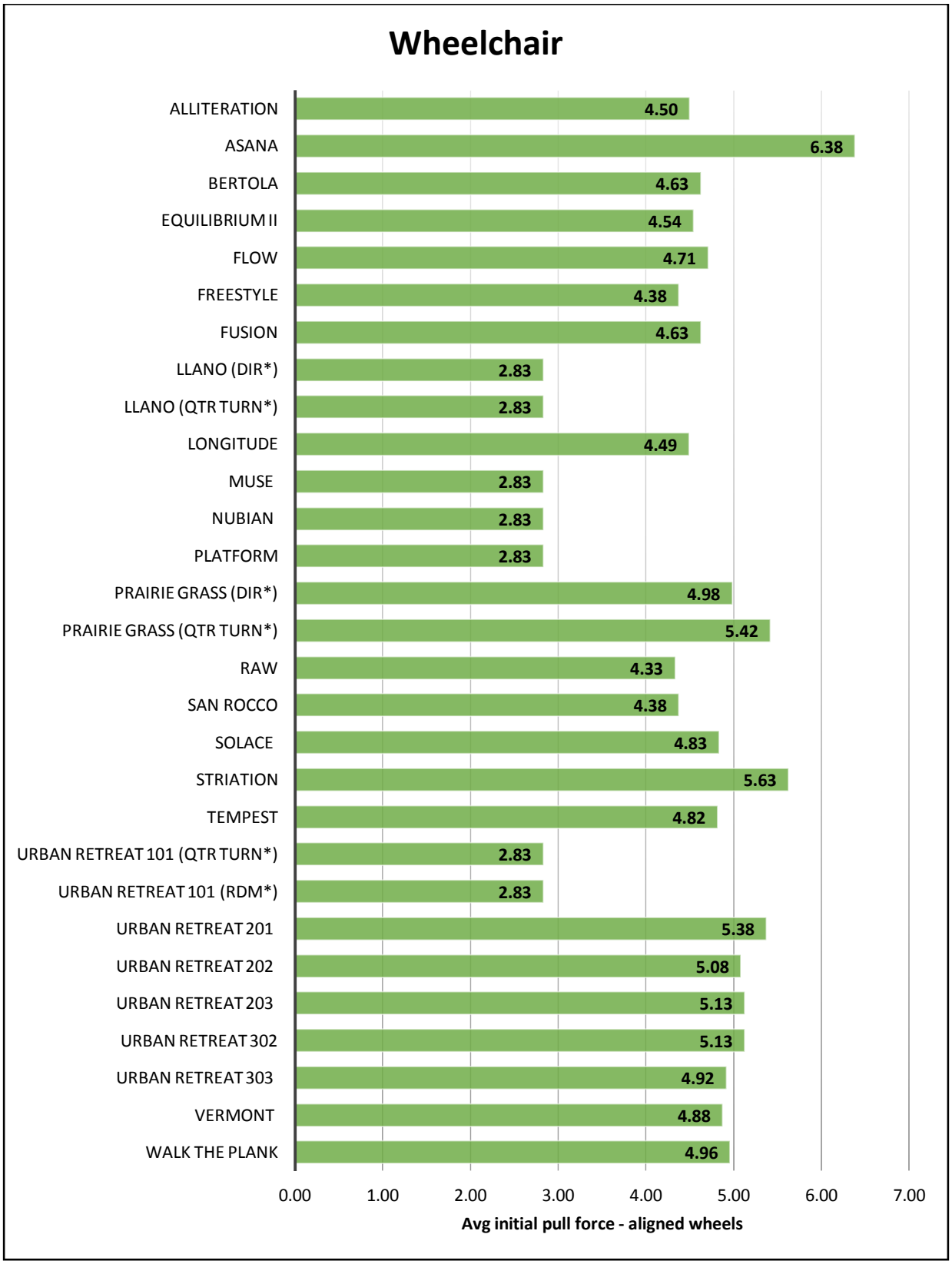
Table 8 Study Two - initial pull forces (kg) – wheels aligned, on the various floor coverings

	Carpet	Installation method	Bed	Wheel chair	Mobile hoist	Walker	Food trolley
1	Alliteration	Directional	16.01	4.50	7.67	1.25	4.96
2	Asana	Random	14.63	6.38	9.63	3.33	8.67
3	Bertola	Directional	14.67	4.63	11.63	1.21	4.25
4	Equilibrium II	Directional	14.13	4.54	11.38	1.25	4.68
5	Flow	Directional	13.33	4.71	10.04	1.54	4.75
6	Freestyle	Directional	13.71	4.38	11.00	1.50	4.13
7	Fusion	Quarter turn	15.79	4.63	12.38	1.50	5.46
8	Llano	Directional	15.33	2.83	11.21	1.75	4.83
9	Llano	Quarter turn	16.13	2.83	10.83	1.96	4.88
10	Longitude	Quarter Turn	14.88	4.49	11.33	1.25	4.97
11	Muse	Ashlar	10.46	2.83	11.25	1.25	5.29
12	Nubian	Quarter turn	14.58	2.83	10.17	1.58	4.50
13	Platform	Directional	14.42	2.83	10.08	1.42	4.50
14	Prairie grass	Directional	14.38	4.98	9.33	1.37	4.61
15	Prairie grass	Quarter turn	16.04	5.42	11.29	1.25	5.00
16	Raw	Random	14.42	4.33	10.54	1.13	4.94
17	San Rocco	Directional	13.58	4.38	10.54	1.54	4.93
18	Solace	Directional	13.88	4.83	9.71	1.46	4.50
19	Striation	Directional	14.63	5.63	11.83	1.50	5.04
20	Tempest	Directional	14.93	4.82	10.58	1.29	4.73
21	Urban retreat 101	Quarter turn	15.46	2.83	11.50	1.50	4.92
22	Urban retreat 101	Random	17.58	2.83	13.88	1.79	5.13
23	Urban retreat 201	Quarter turn	15.38	5.38	13.21	1.58	5.38
24	Urban retreat 202	Directional	15.38	5.08	11.21	1.63	5.08
25	Urban retreat 203	Quarter turn	16.54	5.13	11.54	1.38	5.04
26	Urban retreat 302	Quarter turn	14.38	5.13	10.67	1.63	4.63
27	Urban retreat 303	Directional	15.04	4.92	11.04	1.58	4.54
28	Vermont	Directional	14.88	4.88	10.71	1.38	4.96
29	Walk the plank	Directional	15.25	4.96	11.50	1.38	4.96

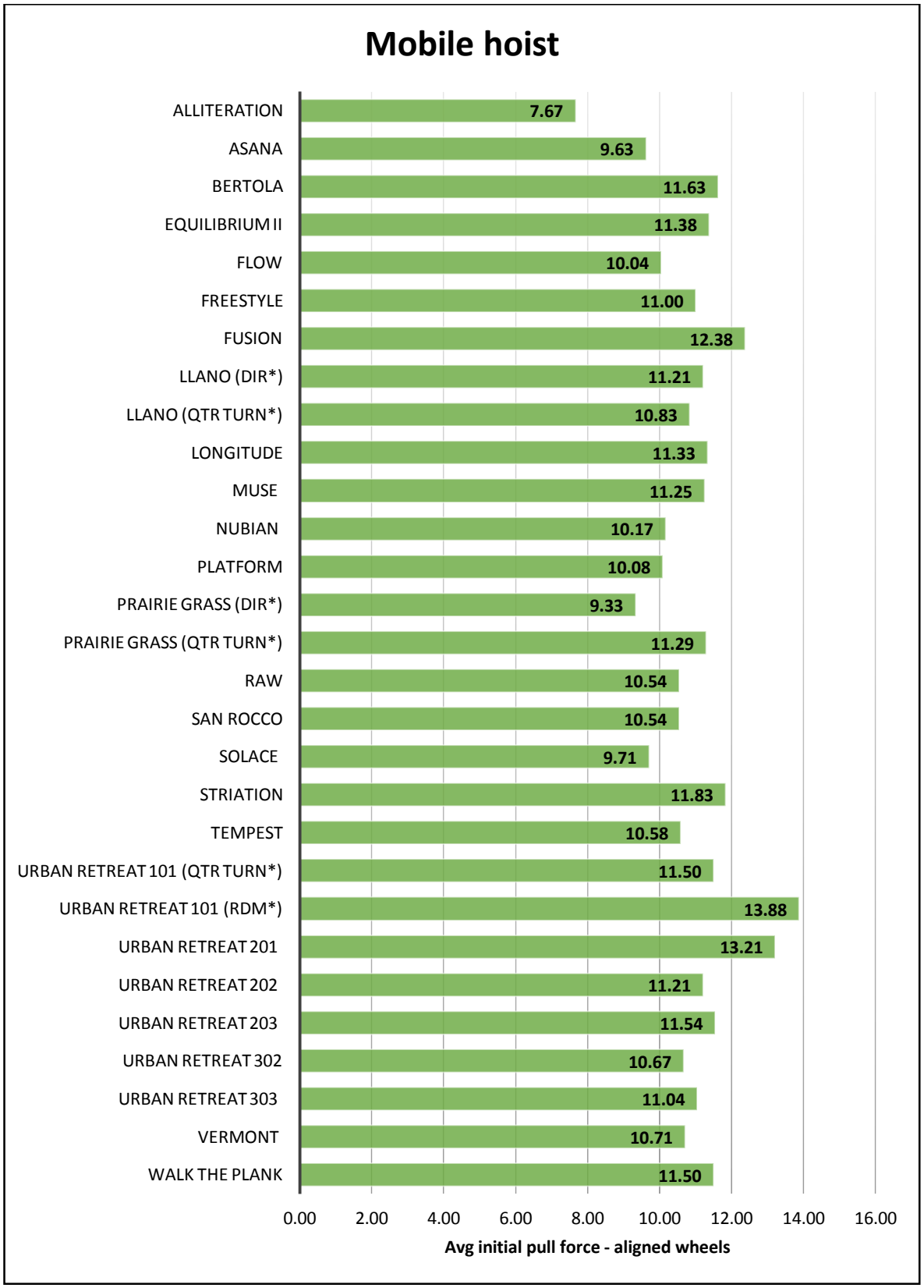
Figure 9 Study Two – chart series of initial pull forces on various floor coverings, wheels aligned, for individual items of equipment.



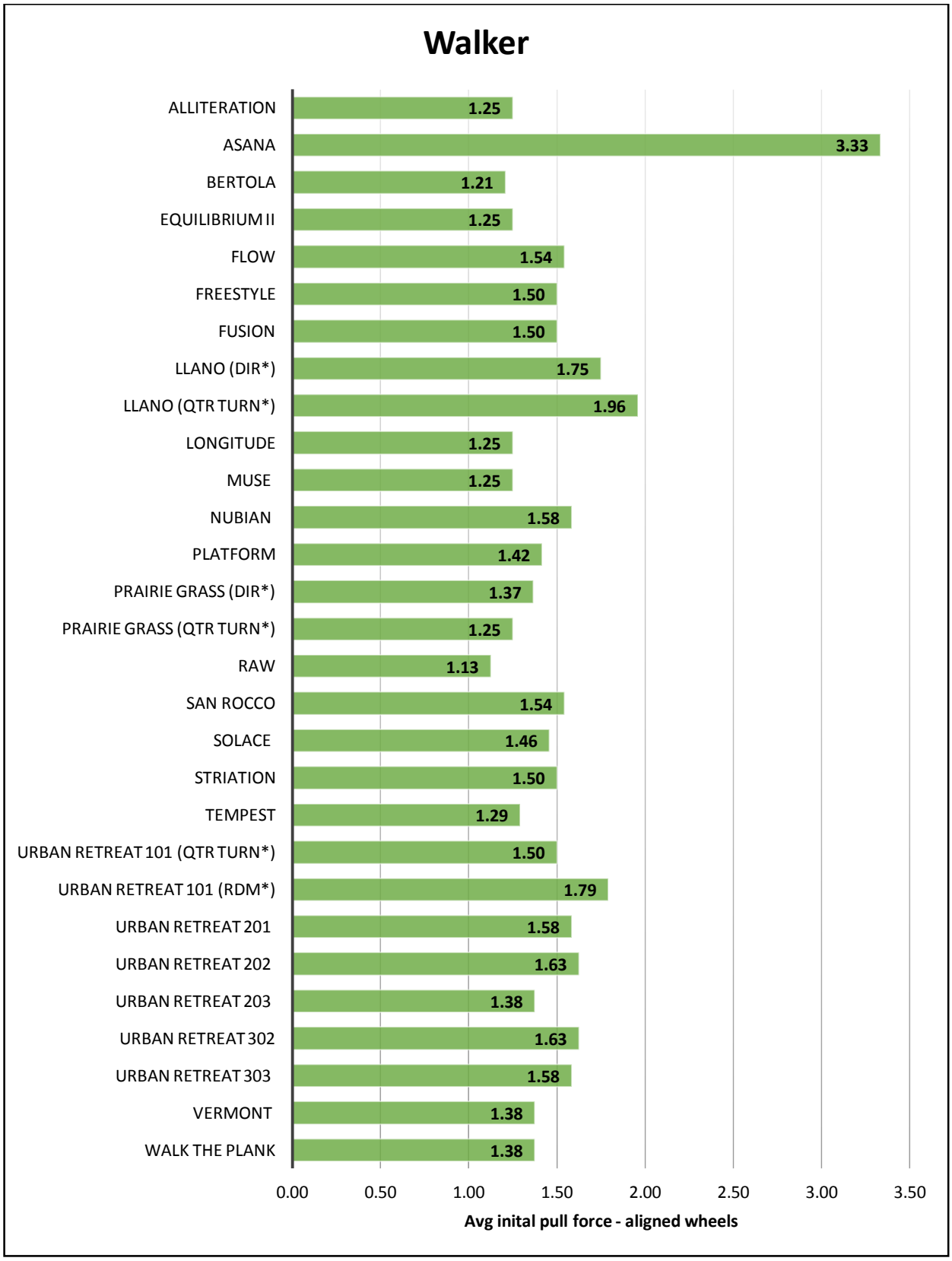
(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



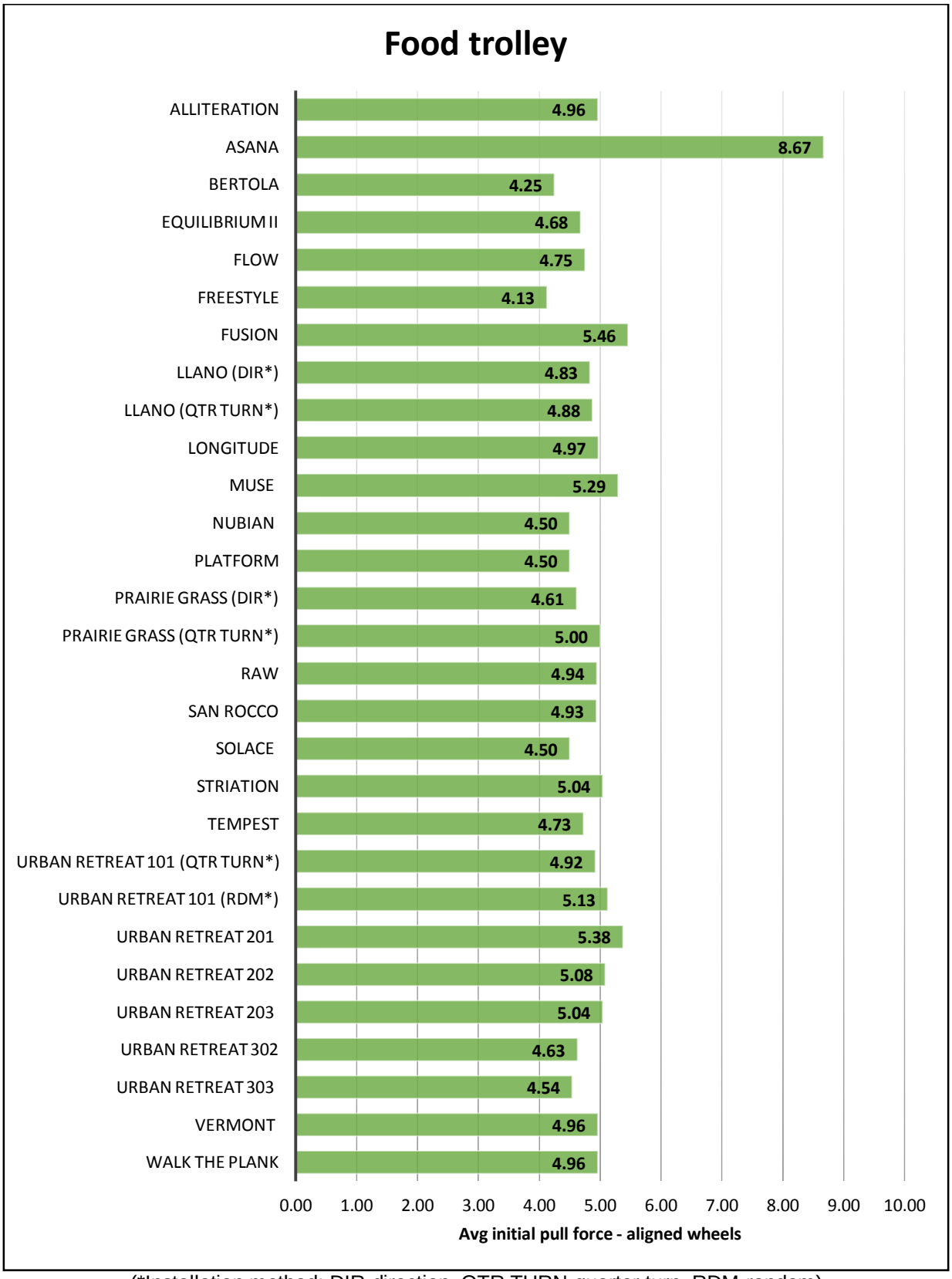
(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)

3.4 Comparison with maximum acceptable initial pull forces

Study One

The initial bed pushing forces were below 19 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.

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 per 5 minutes, or for a distance of 45.7 metres once per 2 minutes, or for a distance of 15.2 metres once every 25 seconds. This is likely to cover most hospital and aged care situations.

All of the Glasbac carpets required 18 kg force or less, which increases the frequency with which beds can be pushed over most distances, or increases the distance for a given frequency.

The maximum initial force measured for pushing a patient lifting machine on any of the surfaces was 11.5 kg. This is within the maximum force acceptable to 75% of the female working population for a distance of 61 metres once per 2 minutes, or for a distance of 45.7 metres once per minute, or for a distance of 2.1 metres once every 6 seconds.

The initial forces to push the food trolley, the walker and the wheelchair were all below 9 kg. This is well within the capability of 75% of the female working population for a 61 metre push every 2 minutes, or for a 7.6 metre push once per 15 seconds. This covers most work situations that are likely to arise.

Study Two

The initial bed push forces with wheels aligned were below 18 kg on all the floor coverings. This is within the range recommended by Lawson and Potiki (1994) of 17 kg to 21 kg for initial force.

Examination of the Snook Tables for handle heights between 90 cm and 135 cm for beds 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 thirty minutes, or for a distance of 15.2 metres every 5 minutes.

- 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 thirty minutes, or for a distance of 15.2 metres every 5 minutes.

The maximum initial force measured for pulling a mobile hoist with wheels aligned on any of the surfaces was 12.4 kg.

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

- an *initial push* force of 13 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 13 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 food trolley with wheels aligned was below 9 kg.

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

- an *initial push* force of 9 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 9 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 walker and wheelchair with wheels aligned were below 7 kg.

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

- an *initial push* force of 7 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 7 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.

3.5 Effect of having the wheels initially not aligned

Study One

The initial push forces required to get the various items of equipment moving on the various floor coverings, starting with the castored wheels set at right angles to the direction of travel, are shown in Table 9, and are illustrated graphically in Figures 10 and 11.

Table 9 Study One - initial push/pull forces, kg, on various floor coverings, with wheels initially set at right angles to direction of travel

	Carpet	Bed	Hoist	Wheel chair	Walker	Food trolley
A	Bioscape Glasbac	24.56	12.6	6.67		
B	Continuum Glasbac	25.12	12.11	5.31		
C	Continuum Cushion	27.54	14.67	6.92		
D	Cubic Colours Glasbac	22.52	11.53	4.84	4.62	9.97
E	Cubic Colours Cushion	25.59	13.48	5.07	4.1	11.8
F	Fast forward Glasbac	22.08	11.99	5.54		
G	Fast forward Cushion	25.61	13.06	6.08		
H	Outlook Glasbac	22.86	12.36	5.62		
I	Outlook Cushion	23.91	13.53	6.06		
J	Rococo Glasbac	23.57	13.46	6.18		
K	Stitched Up Glasbac	25.21	11.63	5.78		
L	Suits you Cushion	27.06	13.47	6.18		
M	Syncopations Glasbac	27.64	13.14	6.16	5.08	11.76
N	Syncopations Cushion	27.93	14.46	6.06	4.34	12.13
O	The Loop Glasbac	24.16	11.9	5.61		
P	The Loop Cushion	27.9	14.12	7.16		
Q	Yin Yang Glasbac	23.59	13.3	6.28		
R	Yin Yang Cushion	27.34	15.53	7.5		

Figure 10 **Study One - initial push forces on various floor coverings, wheels not aligned.**

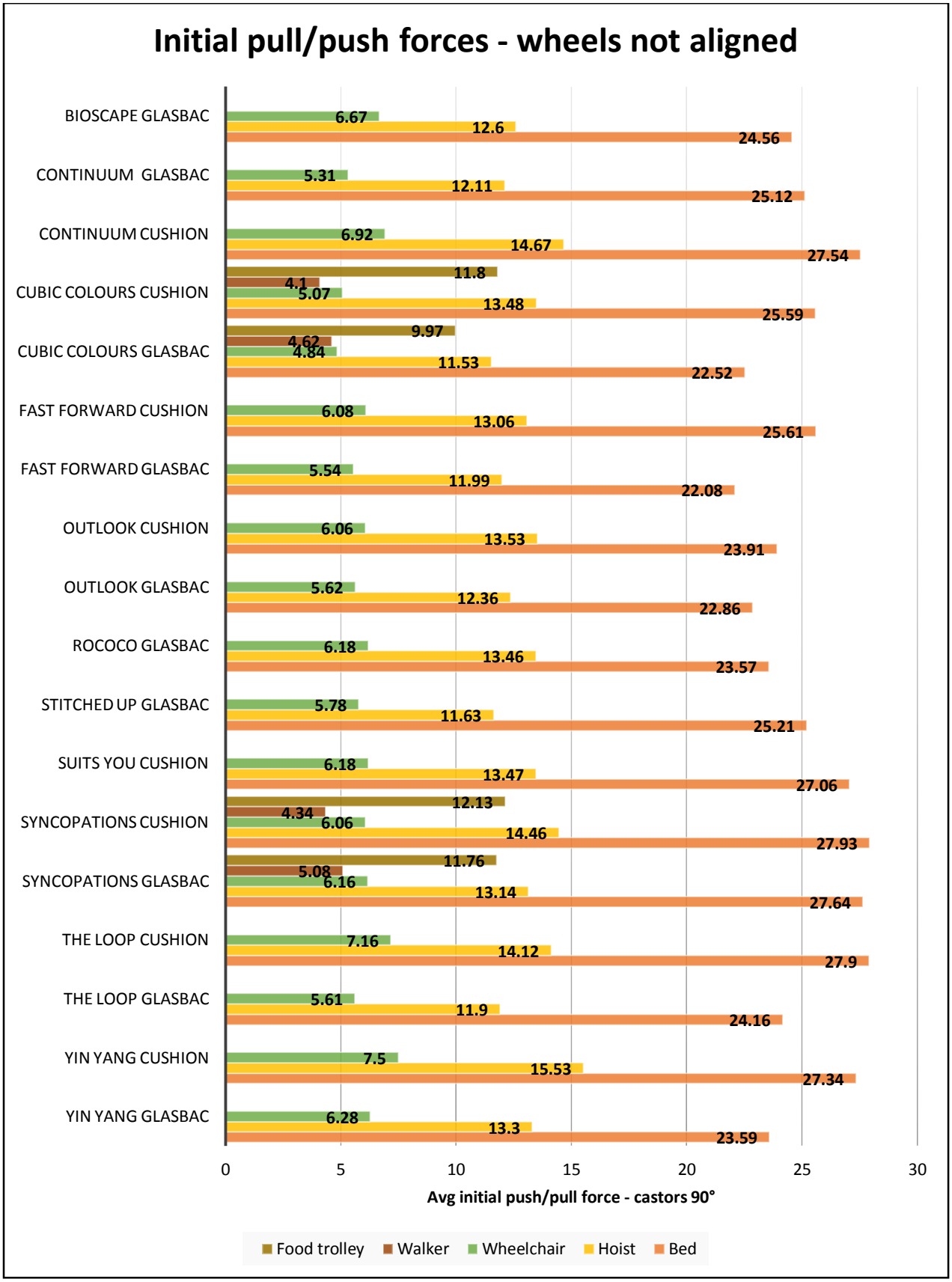
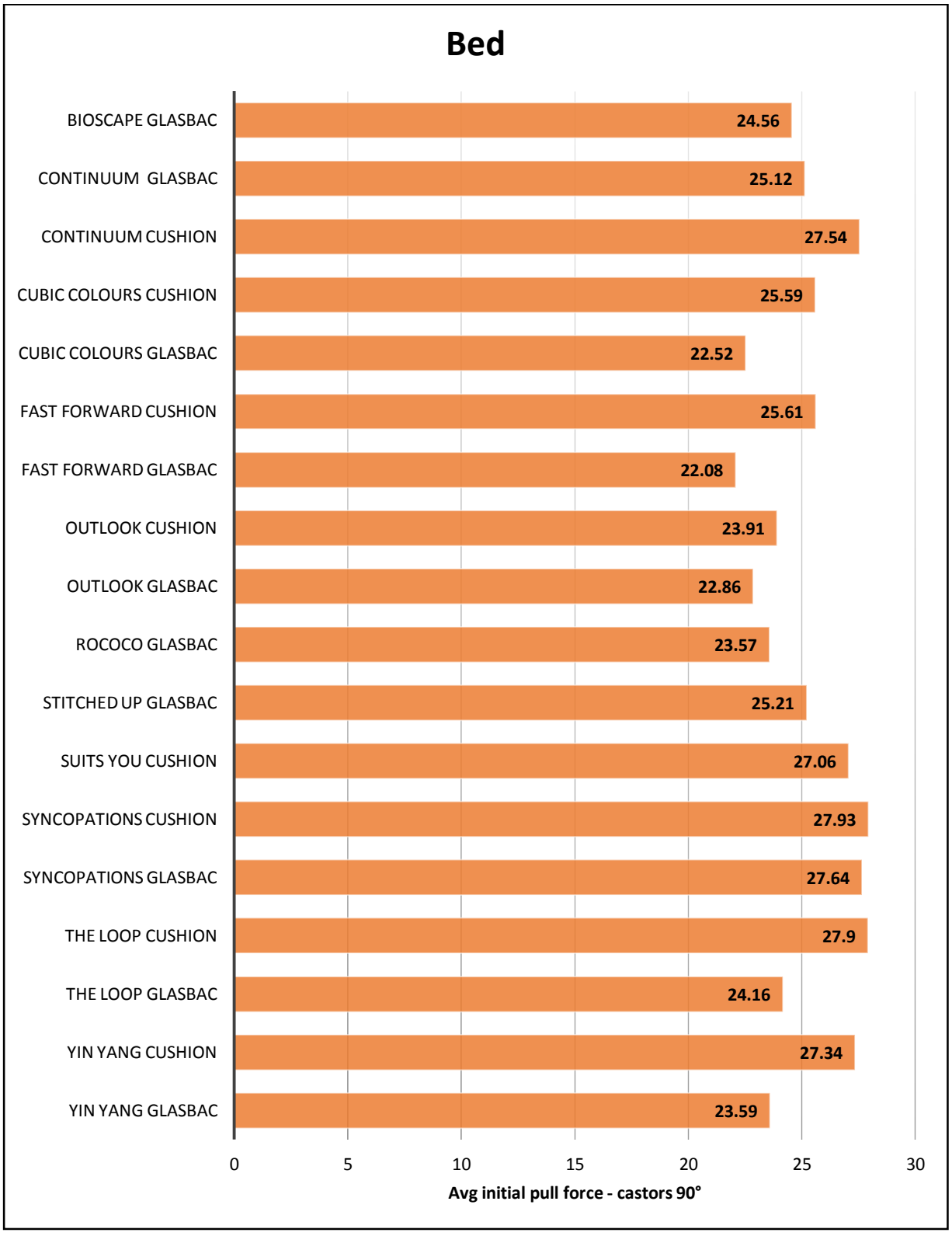
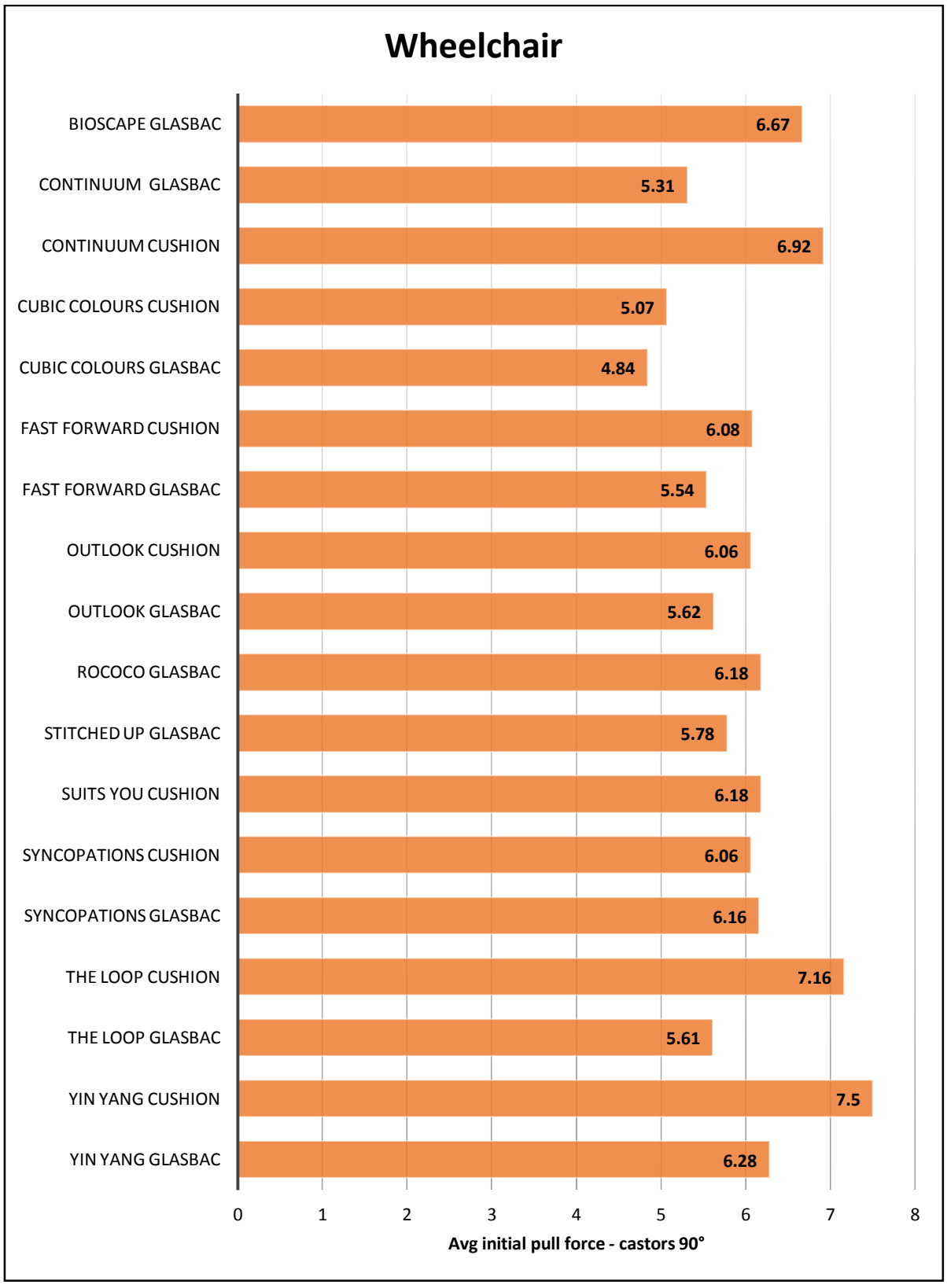
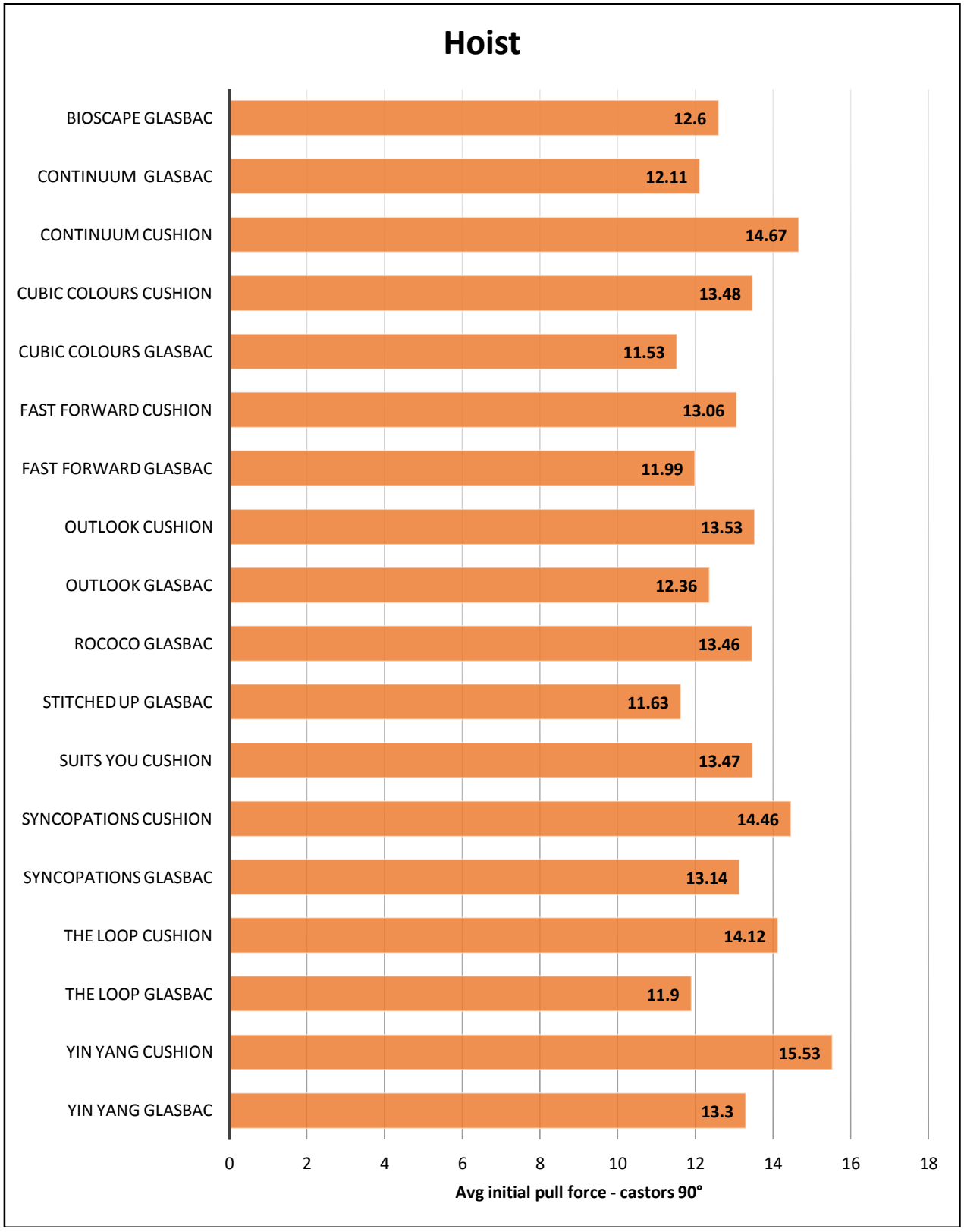
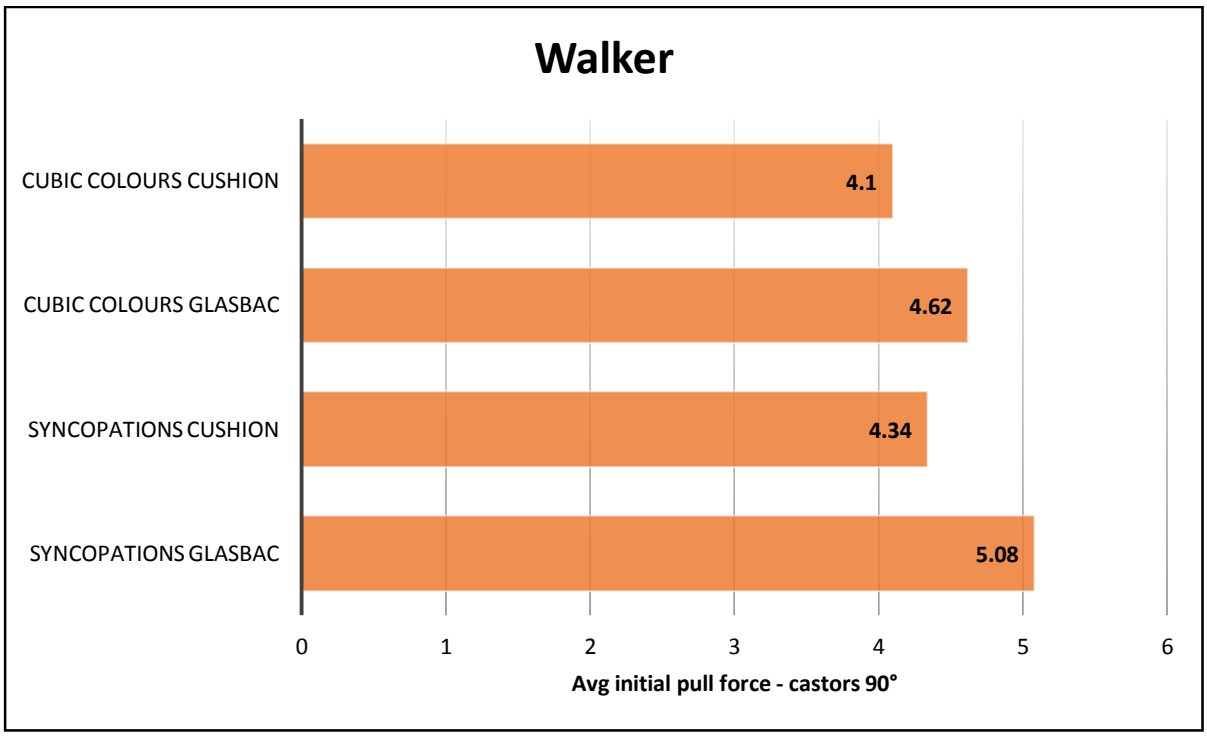


Figure 11 Study One – chart series of initial pull/push forces on various floor coverings, wheels initially not aligned (castors at 90°), for individual items of equipment.




Wheelchair
BIOSCAPE GLASBAC
6.67
CONTINUUM GLASBAC
5.31
CONTINUUM CUSHION
6.92
CUBIC COLOURS CUSHION
5.07
CUBIC COLOURS GLASBAC
4.84
FAST FORWARD CUSHION
6.08
FAST FORWARD GLASBAC
5.54
OUTLOOK CUSHION
6.06
OUTLOOK GLASBAC
5.62
ROCOCO GLASBAC
6.18
STITCHED UP GLASBAC
5.78
SUITS YOU CUSHION
6.18
SYNCOPATIONS CUSHION
6.06
SYNCOPATIONS GLASBAC
6.16
THE LOOP CUSHION
7.16
THE LOOP GLASBAC
5.61
YIN YANG CUSHION
7.5
YIN YANG GLASBAC
6.28
0
1
2
3
4
5
6
7
8
Avg initial pull force - castors 90°


Hoist
BIOSCAPE GLASBAC
12.6
CONTINUUM GLASBAC
12.11
CONTINUUM CUSHION
14.67
CUBIC COLOURS CUSHION
13.48
CUBIC COLOURS GLASBAC
11.53
FAST FORWARD CUSHION
13.06
FAST FORWARD GLASBAC
11.99
OUTLOOK CUSHION
13.53
OUTLOOK GLASBAC
12.36
ROCOCO GLASBAC
13.46
STITCHED UP GLASBAC
11.63
SUITS YOU CUSHION
13.47
SYNCOPATIONS CUSHION
14.46
SYNCOPATIONS GLASBAC
13.14
THE LOOP CUSHION
14.12
THE LOOP GLASBAC
11.9
YIN YANG CUSHION
15.53
YIN YANG GLASBAC
13.3
0
2
4
6
8
10
12
14
16
18
Avg initial pull force - castors 90°

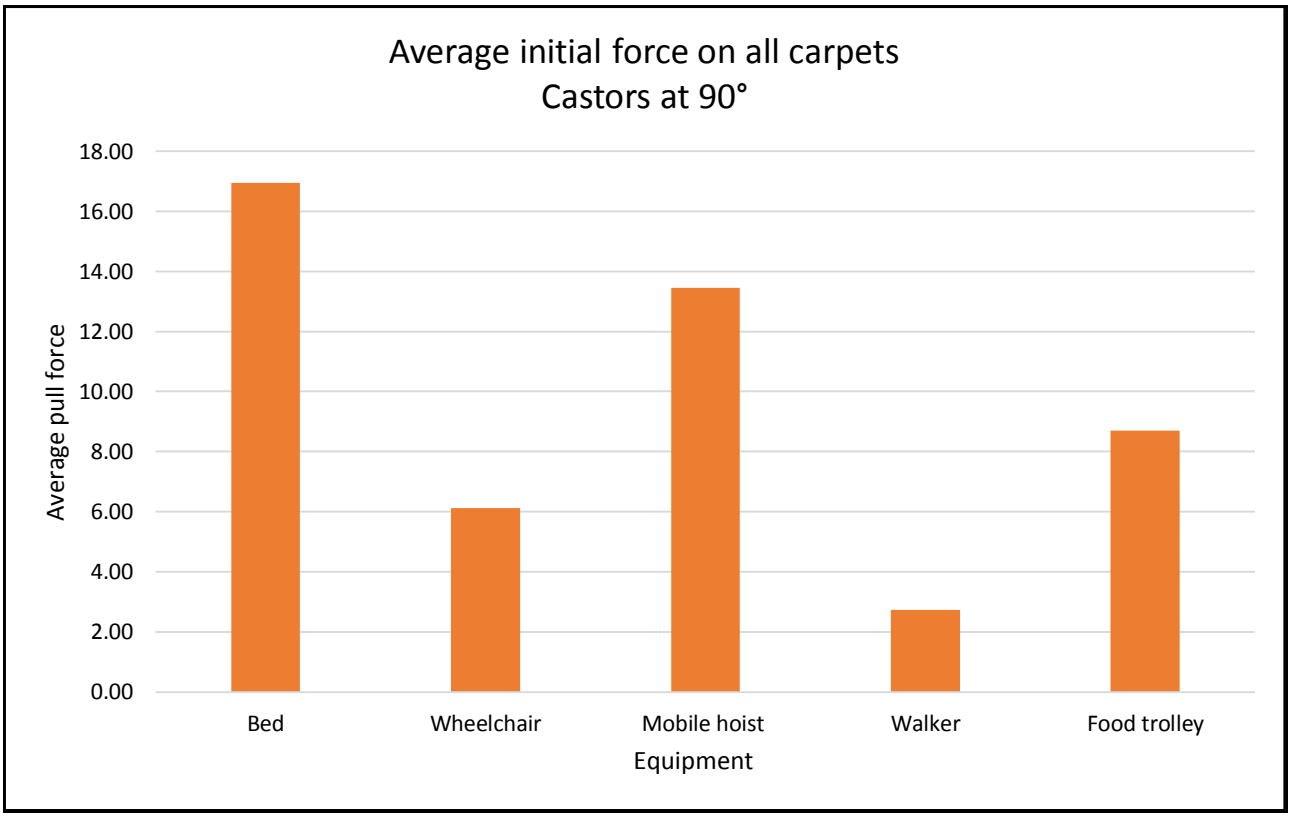

Walker
CUBIC COLOURS CUSHION
CUBIC COLOURS GLASBAC
SYNCOPATIONS CUSHION
SYNCOPATIONS GLASBAC
4.1
4.62
4.34
5.08
0
1
2
3
4
5
6
Avg initial pull force - castors 90°


Food trolley
CUBIC COLOURS CUSHION
CUBIC COLOURS GLASBAC
SYNCOPATIONS CUSHION
SYNCOPATIONS GLASBAC
11.8
9.97
12.13
11.76
0
2
4
6
8
10
12
14
Avg initial pull force - castors 90°

Study Two

The initial forces for each item of hospital equipment with wheels initially not aligned, averaged over all the floor coverings, are shown in Figure 12. The bed was again hardest to move, followed by the mobile hoist. The other equipment was easier to move because of larger diameter wheels and/or a lighter load.

Figure 12 Study One - initial push/pull forces on various floor coverings, wheels not aligned.

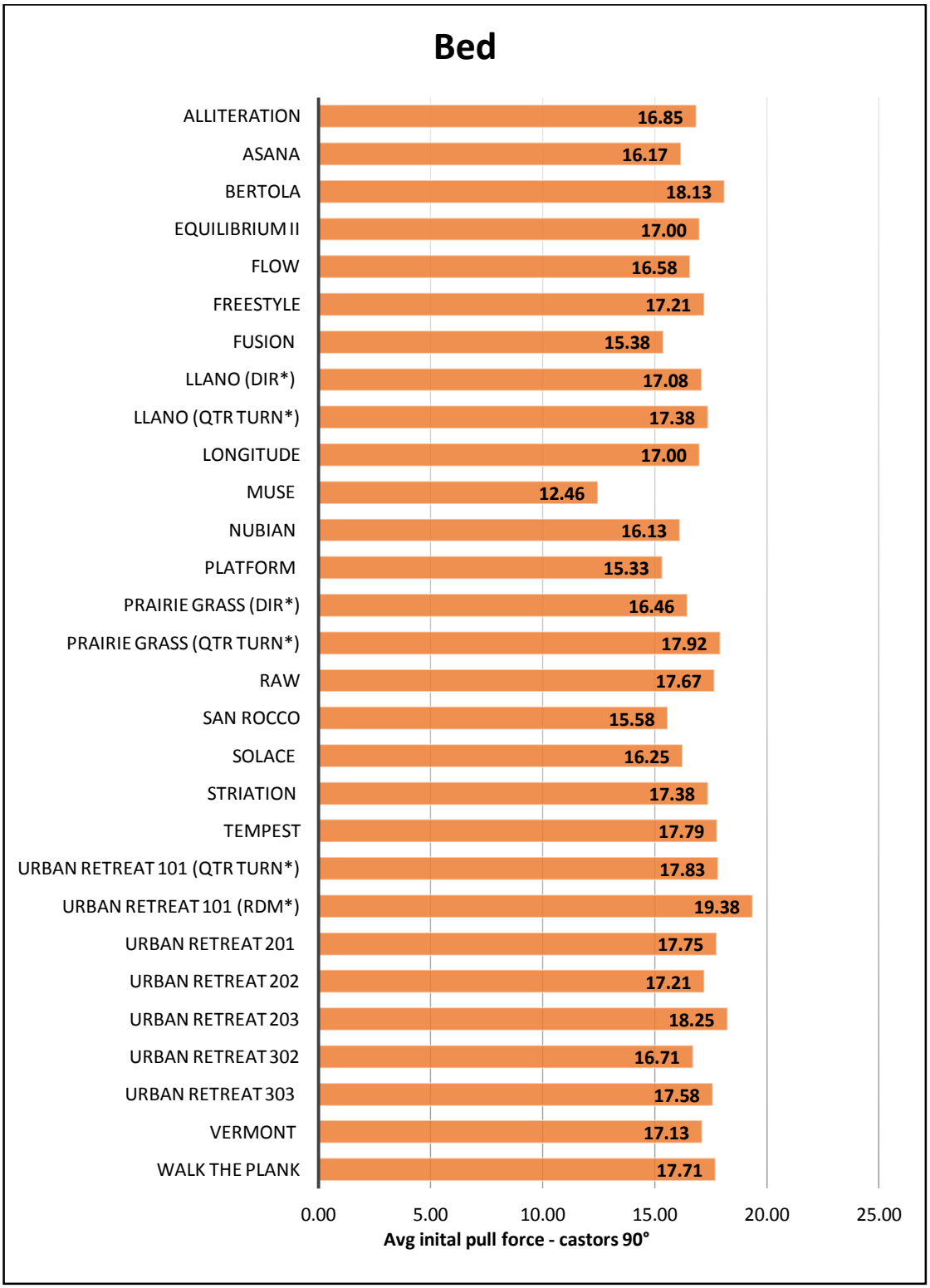


The individual initial pull forces required to get the various items of equipment moving on the various floor coverings, starting with the castored wheels set at right angles to the direction of travel, are shown in Table 10, and are illustrated graphically in Figure 12.

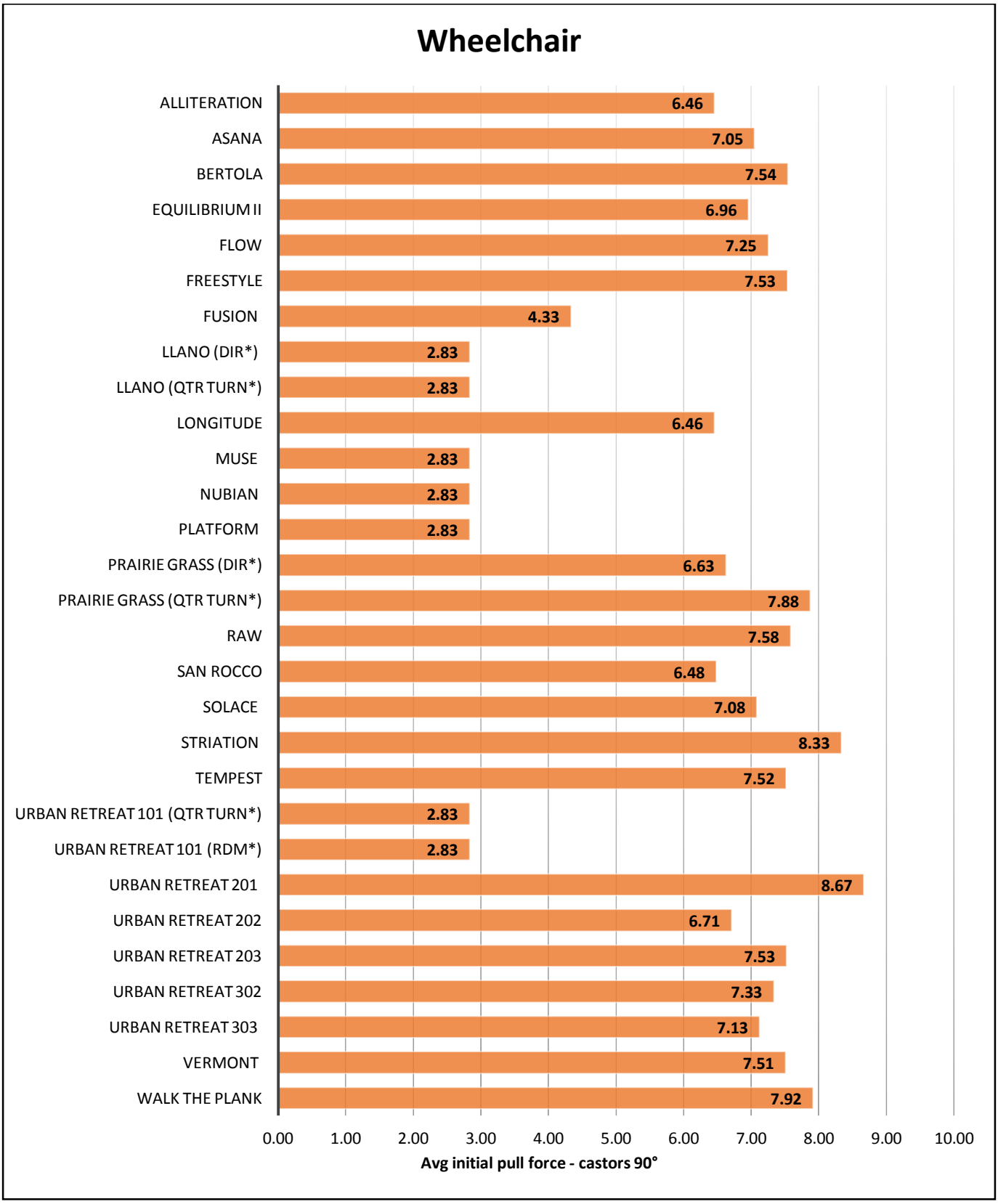
Table 10 Study Two - initial pull forces (kg) on various floor coverings, with wheels initially at right angles to direction of travel

	Carpet	Installation method	Bed	Wheel chair	Mobile hoist	Walker	Food trolley
1	Alliteration	Directional	16.85	6.46	11.13	2.25	8.96
2	Asana	Random	16.17	7.05	12.21	3.42	8.58
3	Bertola	Directional	18.13	7.54	14.29	2.42	9.00
4	Equilibrium II	Directional	17.00	6.96	14.29	2.46	9.79
5	Flow	Directional	16.58	7.25	12.58	2.92	6.08
6	Freestyle	Directional	17.21	7.53	13.17	2.46	8.25
7	Fusion	Quarter turn	15.38	4.33	12.33	1.46	5.71
8	Llano	Directional	17.08	2.83	13.54	3.17	9.25
9	Llano	Quarter turn	17.38	2.83	13.50	2.79	9.25
10	Longitude	Quarter Turn	17.00	6.46	13.29	2.49	7.68
11	Muse	Ashlar	12.46	2.83	12.38	2.88	9.75
12	Nubian	Quarter turn	16.13	2.83	12.13	2.79	7.67
13	Platform	Directional	15.33	2.83	10.75	2.50	7.95
14	Prairie grass	Directional	16.46	6.63	11.67	2.50	8.67
15	Prairie grass	Quarter turn	17.92	7.88	13.08	3.08	9.42
16	Raw	Random	17.67	7.58	14.54	3.67	9.29
17	San Rocco	Directional	15.58	6.48	12.96	2.51	8.24
18	Solace	Directional	16.25	7.08	11.96	2.38	8.33
19	Striation	Directional	17.38	8.33	14.42	2.71	9.21
20	Tempest	Directional	17.79	7.52	12.75	2.21	9.29
21	Urban retreat 101	Quarter turn	17.83	2.83	15.29	2.67	8.88
22	Urban retreat 101	Random	19.38	2.83	16.96	2.88	9.33
23	Urban retreat 201	Quarter turn	17.75	8.67	14.54	2.96	9.17
24	Urban retreat 202	Directional	17.21	6.71	15.33	2.96	8.83
25	Urban retreat 203	Quarter turn	18.25	7.53	14.33	3.04	9.25
26	Urban retreat 302	Quarter turn	16.71	7.33	14.21	2.83	9.13
27	Urban retreat 303	Directional	17.58	7.13	14.58	2.67	8.83
28	Vermont	Directional	17.13	7.51	12.58	2.50	9.04
29	Walk the plank	Directional	17.71	7.92	15.25	4.00	9.75

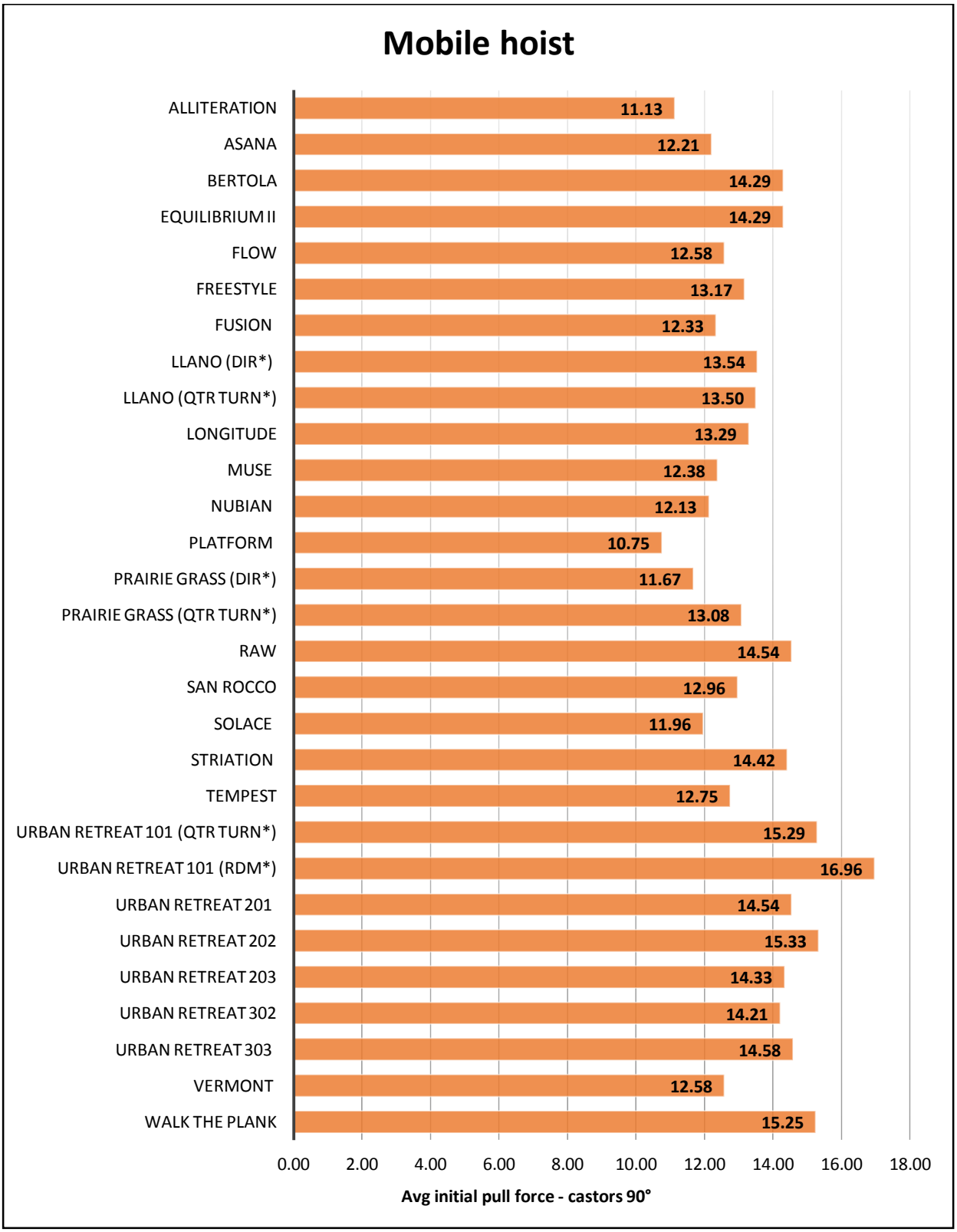
Figure 12 Study One – chart series of initial pull forces on various floor coverings, wheels initially not aligned, for individual items of equipment.



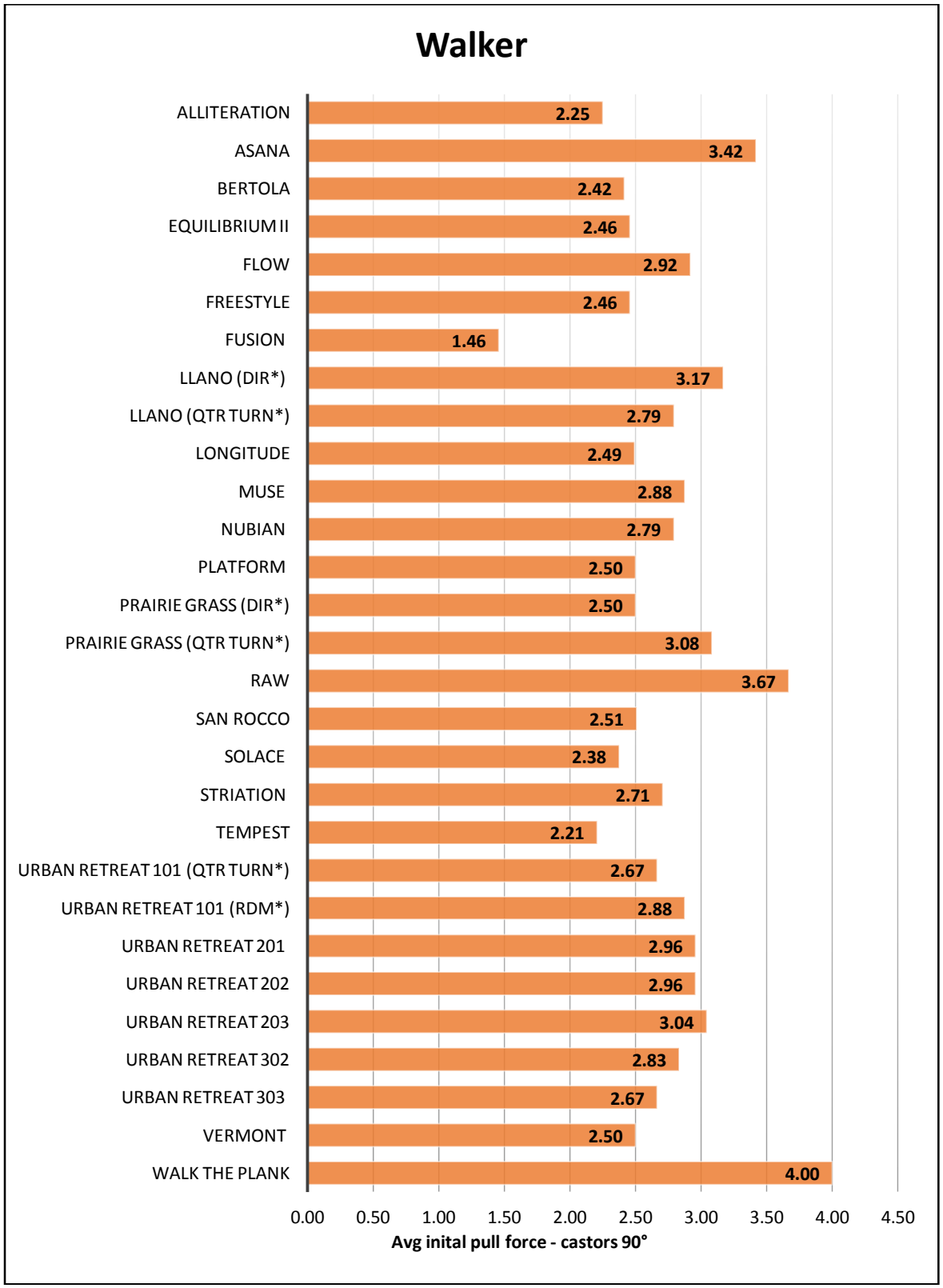
(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



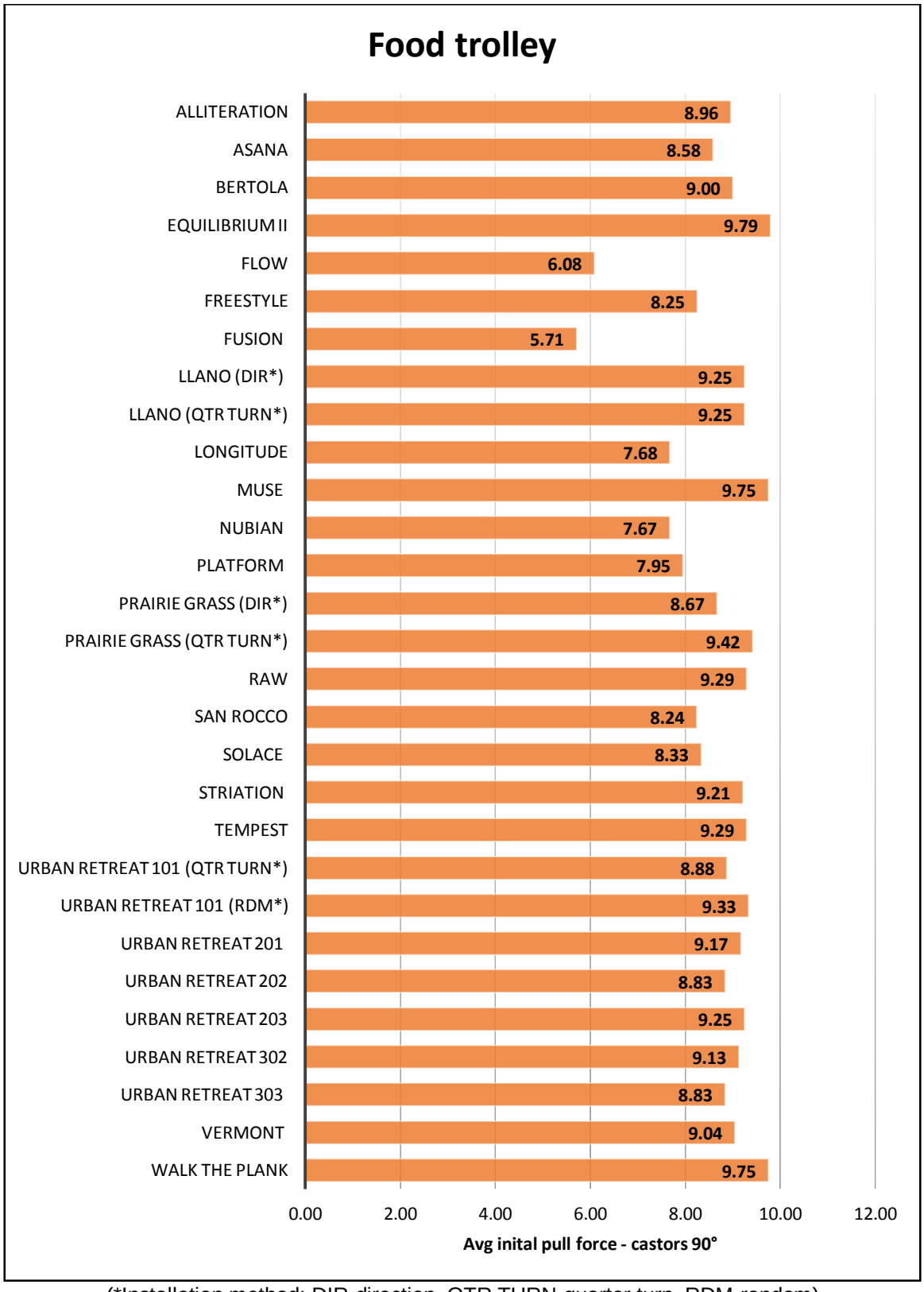
(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)



(*Installation method: DIR-direction, QTR TURN-quarter turn, RDM-random)

3.6 Comparison with maximum acceptable initial push/pull forces, when the wheels are initially set at right angles to the direction of travel

Study One

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 were in the approximate range of 22 to 28 kg on all of the floor coverings. This is beyond 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 22 kg is acceptable to 75% of the female working population for a distance 7.6 metres once per 5 minutes, or for a distance of 2.1 metres once every 2 minutes. 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.

The initial forces measured for pushing a patient lifting machine were in the approximate range of 11 to 16 kg on all of the floor coverings. This is considerably less than the bed pushing forces. 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. It is within the maximum force acceptable to 75% of the female working population for a distance of 45.7 metres once per 5 minutes, or for a distance of 2.1 metres once every 12 seconds. The latter situation is similar to transferring a resident from bed to chair.

The initial forces measured for pushing the meal trolley were in the approximate range of 10 to 12 kg on the four floor coverings tested. This is slightly less than the hoist pushing forces. This is within the capability of 75% of the female working population for a 61 metre push every 2 minutes, or for a 7.6 metre push once per 15 seconds, or a 2.1 metre push every 6 seconds.

The initial forces to push the walker and the wheelchair were all below 6 kg. This is within the capability of 75% of the female working population for a 61 metre push every 2 minutes, or for a 7.6 metre push once per 15 seconds, or a 2.1 metre push every 6 seconds. This covers most typical work situations.

Study Two

The initial bed pulling forces with the castors not aligned were in the approximate range of 12.5 kg to 19.5 kg on all the floor coverings tested (the maximum was 19.4 kg). This is within 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. These results may reflect better quality castors on the equipment tested in Study Two.

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

- *An initial push* force of 19.4 kg is acceptable to 75% of the female working population for a distance 45.7 metres every eight hours, or for a distance of 2.1 metres every minute.

- *An initial pull* force of 19.4 kg is acceptable to 75% of the female working population for a distance 45.7 metres every eight hours, or for a distance of 2.1 metres every minute.

Observation: 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 pulling at right angles to the wheels when they are stationary. Where practicable, powered tuggers should be used to move the beds. A further option would be for two staff to get the bed moving, after which one staff member may provide the sustained push or pull force, subject to the frequency and distance being acceptable.

The initial forces measured for pulling a mobile hoist with the wheels initially not aligned were in the approximate range of 11 kg to 17 kg on 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 17 kg is acceptable to 75% of the female working population for a distance of 61 metres every thirty minutes, or for a distance of 45.7 metres every 5 minutes, or for a distance of 2.1 metres every 6 seconds.

- *An initial pull* force of 17 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 5 minutes, or for a distance of 2.1 metres every 12 seconds.

The initial forces measured for pulling the meal trolley were in the approximate range of 6 kg to 10 kg. This is less than the hoist pulling forces.

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

- *An initial pull* force of 10 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 10 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 and the wheelchair were below 9 kg.

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

- *An initial push* force of 9 kg is within the capability of 75% of the female working population for a distance of 61 metres every 2 minutes, or for a distance of 7.6 metres every 15 seconds, or for a distance of 2.1 metres every 6 seconds. This covers most typical work situations.

- *An initial pull* force of 9 kg is within the capability of 75% of the female working population for a distance of 61 metres every 2 minutes, or for a distance of 7.6 metres every 15 seconds, or for a distance of 2.1 metres every 6 seconds. This covers most typical work situations.

4 Discussion

4.1 Considerations in interpreting results

The measurements were carried out in both rounds of tests on a horizontal solid floor, and 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 equipment used was not new in either round of tests, 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. 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 en suite occasionally during the day, but this may require less tight turning and manoeuvring, thus making it easier for staff, regardless of the floor covering.

4.2 Comparison of different equipment

The results across both rounds of tests show that the initial and sustained forces to pull the walker and the wheelchair are low on all surfaces, even with the wheels initially at right angles to the intended direction of travel. The meal trolley required slightly higher forces, which were still within acceptable forces for distances of 61 metres every 2 minutes, even when the wheels were not aligned.

The forces for the hoist and the bed are higher than for the other items of equipment. Table 11 sets out acceptable frequencies for sustained solo pulling of the trial bed over various distances. Note that more modern beds are likely to move more freely, as are beds with less weight. Pull forces have been rounded up to the next closest kilogram force e.g. 11.05 kg = 12 kg.

Table 11 Study One - acceptable frequencies for sustained pushing of the trial bed over various distances (according to Snook and Ciriello, 1991), by a solo female worker. N/A = not acceptable

Distance		2.1 m	7.6 m	15.2 m	30.5 m	45.7 m	61.0 m
Floor covering	Force, kg	Frequency: 75% of female work force may push the bed used in these trials over stated distance once every…					
Bioscape Glasbac	9.46	6 sec	15 sec	25 sec	1 min	2 min	5 min
Continuum Glasbac	8.06	6 sec	15 sec	25 sec	1 min	1 min	2 min
Continuum Cushion	10.26	6 sec	15 sec	25 sec	1 min	2 min	5 min
Cpubic Colours Glasbac	6.62	6 sec	15 sec	25 sec	1 min	1 min	2 min
Cubic Colours Cushion	8.43	6 sec	15 sec	25 sec	1 min	1 min	2 min
Fast forward Glasbac	8	6 sec	15 sec	25 sec	1 min	1 min	2 min
Fast forward Cushion	9.97	6 sec	15 sec	25 sec	1 min	2 min	5 min
Outlook Glasbac	8.96	6 sec	15 sec	25 sec	1 min	1 min	2 min
Outlook Cushion	9.77	6 sec	15 sec	25 sec	1 min	2 min	5 min
Rococo Glasbac	9.7	6 sec	15 sec	25 sec	1 min	2 min	5 min
Stitched Up Glasbac	9.76	6 sec	15 sec	25 sec	1 min	2 min	5 min
Suits you Cushion	9.46	6 sec	15 sec	25 sec	1 min	2 min	5 min
Syncopations Glasbac	9.14	6 sec	15 sec	25 sec	1 min	2 min	5 min
Syncopations Cushion	9.82	6 sec	15 sec	25 sec	1 min	2 min	5 min
The Loop Glasbac	8.8	6 sec	15 sec	25 sec	1 min	1 min	2 min
The Loop Cushion	10.92	6 sec	15 sec	25 sec	1 min	2 min	5 min
Yin Yang Glasbac	9.21	6 sec	15 sec	25 sec	1 min	2 min	5 min
Yin Yang Cushion	10.19	6 sec	15 sec	25 sec	1 min	2 min	5 min
Broadloom Hessian backed	10.85	6 sec	15 sec	25 sec	1 min	2 min	5 min

Table 12 sets out acceptable frequencies for sustained pushing of the mobile hoist. Distances over 30.5 metres have not been included, because hoists are not normally used outside bedrooms or bathrooms due to patient dignity considerations.

Table 12 Study One - acceptable frequencies for sustained pushing of the mobile hoist over various distances (according to Snook and Ciriello, 1991 – push forces rounded to nearest whole number of kg for calculation).

Distance		2.1 m	7.6 m	15.2 m	30.5 m
Floor covering	Force, kg	Frequency: 75% of female work force may push mobile hoist over stated distance once every…			
Bioscape Glasbac	6.22	6 sec	15 sec	25 sec	1 min
Continuum Glasbac	6.42	6 sec	15 sec	25 sec	1 min
Continuum Cushion	7.76	6 sec	15 sec	35 sec	1 min
Cubic Colours Glasbac	5.90	6 sec	15 sec	25 sec	1 min
Cubic Colours Cushion	7.19	6 sec	15 sec	25 sec	1 min
Fast forward Glasbac	6.72	6 sec	15 sec	25 sec	1 min
Fast forward Cushion	7.40	6 sec	15 sec	35 sec	1 min
Outlook Glasbac	6.35	6 sec	15 sec	25 sec	1 min
Outlook Cushion	7.82	6 sec	15 sec	35 sec	1 min
Rococo Glasbac	7.03	6 sec	15 sec	25 sec	1 min
Stitched Up Glasbac	6.76	6 sec	15 sec	25 sec	1 min
Suits you Cushion	8.09	6 sec	15 sec	35 sec	1 min
Syncopations Glasbac	7.05	6 sec	15 sec	25 sec	1 min
Syncopations Cushion	8.34	12 sec	15 sec	1 min	1 min
The Loop Glasbac	6.55	6 sec	15 sec	25 sec	1 min
The Loop Cushion	7.80	6 sec	15 sec	35 sec	1 min
Yin Yang Glasbac	7.09	6 sec	15 sec	25 sec	1 min
Yin Yang Cushion	8.09	6 sec	15 sec	35 sec	1 min

Table 13 **Study Two - acceptable frequencies for sustained pulling of the trial bed over various distances by a solo female worker, and with handholds not greater than 135 cm high (according to Snook and Ciriello, 1991).**
N/A = not acceptable

Distance			2.1 m	7.6 m	15.2 m	30.5 m	45.7 m	61.0 m
Floor covering	**Installation method**	**Force, kg**	Frequency: 75% of female work force may pull the bed used in these trials over stated distance once every…					
Alliteration	Directional	11.05	12 sec	1 min	30 min	8 hrs	-	-
Asana	Random	11.67	12 sec	1 min	30 min	8 hrs	-	-
Bertola	Directional	11.83	12 sec	1 min	30 min	8 hrs	-	-
Equilibrium II	Directional	12.17	1 min	5 min	8 hrs	8 hrs	-	-
Flow	Directional	11.08	12 sec	1 min	30 min	8 hrs	-	-
Freestyle	Directional	11.29	12 sec	1 min	30 min	8 hrs	-	-
Llano	Directional	11.58	12 sec	1 min	30 min	8 hrs	-	-
Llano	Quarter turn	12.08	1 min	5 min	8 hrs	8 hrs	-	-
Longitude	Quarter Turn	11.71	12 sec	1 min	30 min	8 hrs	-	-
Meld	Quarter turn	10	12 sec	22 sec	1 min	5 min	8 hrs	8 hrs
Muse	Ashlar	7.5	6 sec	15 sec	35 sec	1 min	1 min	8 hrs
Nubian	Quarter turn	11.25	12 sec	1 min	30 min	8 hrs	-	-
Platform	Directional	11	12 sec	22 sec	5 min	8 hrs	-	-
Prairie grass	Directional	11.67	12 sec	1 min	30 min	8 hrs	-	-
Prairie grass	Quarter turn	12.25	1 min	5 min	8 hrs	8 hrs	-	-
Raw	Random	11.83	12 sec	1 min	30 min	8 hrs	-	-
San Rocco	Directional	12.58	1 min	5 min	8 hrs	8 hrs	-	-
Solace	Directional	11.88	12 sec	1 min	30 min	8 hrs	-	-
Striation	Directional	11.75	12 sec	1 min	30 min	8 hrs	-	-
Tempest	Directional	12.04	1 min	5 min	8 hrs	8 hrs	-	-
Urban retreat 101	Quarter Turn	12.5	1 min	5 min	8 hrs	8 hrs	-	-
Urban retreat 101	Random	12.42	1 min	5 min	8 hrs	8 hrs	-	-
Urban retreat 201	Quarter Turn	12.33	1 min	5 min	8 hrs	8 hrs	-	-
Urban retreat 202	Directional	11.5	12 sec	1 min	30 min	8 hrs	-	-
Urban retreat 203	Quarter Turn	12.33	1 min	5 min	8 hrs	8 hrs	-	-
Urban retreat 302	Quarter Turn	11.42	12 sec	1 min	30 min	8 hrs	-	-
Urban retreat 303	Directional	12.21	1 min	5 min	8 hrs	8 hrs	-	-
Vermont	Directional	12.75	1 min	5 min	8 hrs	8 hrs	-	-
Walk the plank	Directional	13.33	2 min	30 min	8 hrs	8 hrs	-	-

Table 14 sets out acceptable frequencies for sustained pulling of the mobile hoist. Distances over 30.5 metres have not been included because hoists are not normally used outside bedrooms or bathrooms, due to patient dignity considerations. Pull forces were again rounded up to the nearest whole number of kg for calculation.

Table 14 Study Two - acceptable frequencies for sustained pulling of the mobile hoist over various distances for a solo female worker, and with handholds not greater than 135 cm high (according to Snook and Ciriello, 1991).

Distance			2.1 m	7.6 m	15.2 m	30.5 m
Floor covering	**Installation method**	**Force, kg**	Frequency: 75% of female work force may pull mobile hoist over stated distance once every…			
Alliteration	Directional	**6.47**	6 sec	15 sec	25 sec	1 min
Asana	Random	**6.7**	6 sec	15 sec	25 sec	1 min
Bertola	Directional	**7.57**	6 sec	15 sec	35 sec	1 min
Equilibrium II	Directional	**7.47**	6 sec	15 sec	35 sec	1 min
Flow	Directional	**6.33**	6 sec	15 sec	25 sec	1 min
Freestyle	Directional	**6.93**	6 sec	15 sec	25 sec	1 min
Llano	Directional	**7.53**	6 sec	15 sec	35 sec	1 min
Llano	Quarter turn	**7.14**	6 sec	15 sec	35 sec	1 min
Longitude	Quarter Turn	**7.31**	6 sec	15 sec	35 sec	1 min
Meld	Quarter turn	**7.31**	6 sec	15 sec	35 sec	1 min
Muse	Ashlar	**7.4**	6 sec	15 sec	35 sec	1 min
Nubian	Quarter turn	**6.92**	6 sec	15 sec	25 sec	1 min
Platform	Directional	**6.75**	6 sec	15 sec	25 sec	1 min
Prairie grass	Directional	**6.58**	6 sec	15 sec	25 sec	1 min
Prairie grass	Quarter turn	**7.08**	6 sec	15 sec	35 sec	1 min
Raw	Random	**7.47**	6 sec	15 sec	35 sec	1 min
San Rocco	Directional	**7.33**	6 sec	15 sec	35 sec	1 min
Solace	Directional	**6.63**	6 sec	15 sec	25 sec	1 min
Striation	Directional	**7.25**	6 sec	15 sec	35 sec	1 min
Tempest	Directional	**7.45**	6 sec	15 sec	35 sec	1 min
Urban retreat 101	Quarter Turn	**7.75**	6 sec	15 sec	35 sec	1 min
Urban retreat 101	Random	**8.5**	12 sec	15 sec	35 min	2 min
Urban retreat 201	Quarter Turn	**7.52**	6 sec	15 sec	35 sec	1 min
Urban retreat 202	Directional	**7.08**	6 sec	15 sec	35 sec	1 min
Urban retreat 203	Quarter Turn	**7.38**	6 sec	15 sec	35 sec	1 min
Urban retreat 302	Quarter Turn	**6.67**	6 sec	15 sec	25 sec	1 min
Urban retreat 303	Directional	**6.92**	6 sec	15 sec	25 sec	1 min
Vermont	Directional	**7.45**	6 sec	15 sec	35 sec	1 min
Walk the plank	Directional	**7.53**	6 sec	15 sec	35 sec	1 min

5 Conclusions

This two-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 are indicative of what exists in health and aged care agencies, but they do not represent the whole 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 each series of tests, the tests do provide an objective comparison of the relative characteristics of the different floor surfaces tested.

Over all of the test measurements, 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.

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.

Study One

The sustained bed 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.

The forces required to push the mobile hoist were within a force acceptable to 75% of the female workforce for a sustained push of 30.5 metres once every minute on all surfaces.

The sustained and initial (wheels aligned) forces for the other three items of equipment were within acceptable push force limits under all frequencies and distances on the Snook tables.

Study Two

Seventeen of the sustained bed pulling forces were below 12 kg on all the floor coverings. The other 12 floor coverings exceeded this force by a small margin. The range recommended by Lawson and Potiki (1994) is between 6 kg and 12 kg for sustained force.

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

- a *sustained pull* force of 12 kg is acceptable to 75% of the female working population for a distance of 45.7 metres every 8 hours, or 7.6 metres every minute.

- a *sustained push* force of 12 kg is acceptable to 75% of the female working population for a distance of 30.5 metres every 8 hours, or 7.6 metres every five minutes.

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

- a *sustained pull* force of 9 kg required to push the mobile hoist was within the force acceptable to 75% of the female workforce for a distance of 61 metres every eight hours, 30.5 metres every two minutes, or 2.1 metres every twelve seconds on all surfaces.

- a *sustained push* force of 9 kg required to push the mobile hoist was within the force acceptable to 75% of the female workforce for a distance of 61 metres every eight hours, 30.5 metres every five minutes, or 2.1 metres every six seconds on all surfaces.

The sustained and initial (wheels aligned) forces for the other three items of equipment were within acceptable force limits, under all frequencies and distances on the Snook Tables.

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, such as small wheels and a mechanical disadvantage, which 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.

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 19 kg in Study One or 18 kg in Study Two 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.

6 References

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

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Mark was co-author of the first edition of *Designing Workplaces for Safer Handling of Patients/Residents* (WorkSafe Victoria, 1998), and *Transferring People Safely* (WorkSafe Victoria, 2002). Glen was WorkSafe Victoria''s consulting ergonomist in the preparation for publication of the 3rd edition of *Designing Workplaces for Safer Handling of People* (WorkSafe Victoria, 2007).