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HEALTH & SAFETY LABORATORY

Manual handling in kerbside collection and sorting of recyclables

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CONTENTS

EXECUTIVE SUMMARY

An investigation into the risks for musculoskeletal disorders (MSDs) to waste/recycling collectors engaged in kerbside collection of recyclables was undertaken to provide authoritative guidance on control measures to limit risk within existing systems. The work focused specifically on the risks associated with the collection of recyclables in boxes and the sorting of the recyclables on or alongside the vehicle. Data utilised in this report were collected from site visits to operational recycling rounds, and from box and vehicle manufacturers. The data collected includes video footage, photographs, box and vehicle dimensions and box weights. The following aspects of box collection schemes were studied: receptacle and handle design, load, vehicle design and influence on posture, lifting frequency and technique, carry distance, environmental factors and work organisation. A range of control measures to reduce the risks of MSDs was identified from the investigation.

Objectives

1. To identify risk factors for MSDs in box recycling collection schemes.

2. To provide recommendations for reducing the risks of MSDs to waste/recycling collectors.

Main Findings

1. The maximum kerbside collection box weights observed in the laboratory were higher for mixed glass and newspaper than for glass only. The highest maximum box weight observed in the laboratory for mixed glass and newspaper was 22.1kg.

2. The use of a lid reduced the kerbside collection box weights observed in the laboratory for both glass only and mixed glass and newspaper.

3. Kerbside collection box weights appear to be lower where recyclables are collected weekly when compared to bi-weekly collections.

4. The length and width dimensions of kerbside collection boxes do not exceed proposed upper limits of an optimal container design. However, container depth does exceed the recommended upper limit.

5. The handle design of the boxes could be improved to meet the recommended type and dimensions. In particular the handholds should be designed to account for the use of protective gloves.

6. There is little difference in terms of injury risk when lifting kerbside collection boxes of varying dimensions, including lifting those of reduced depth.

7. The National Institute of Occupational Safety and Health (NIOSH) recommend a maximum compressive force of 3.4kN on the L5/S1 intervertebral disc. It is believed there is an increase in risk of low back injury to some workers where the limit of 3.4kN is exceeded. All of the kerbside collection boxes assessed reached the limit of 3.4kN, for males, at a weight of 13kg when lifting in a stooped posture.

8. The revised Manual Materials Handling Guidelines (Liberty Mutual, 2004) suggest that more than 90% of the British male and 20% of the British female adult population would find it acceptable to lift an 11.38 kg box (an average observed from the recycling schemes studied) twice a minute for a period of 8hours.

9. When loading recyclables into either the hoppers or stillages of the collection vehicle, lifting above shoulder height was observed. This is known to increase the risk of injury. The results of a Rapid Entire Body Assessment (REBA) indicate that lifting above shoulder height created a ‘high’ risk posture and action is necessary ‘soon’.

10. When loading recyclables on-board the vehicle, lifting above shoulder height and twisting were observed due to restriction on movement caused by space constraints. In some cases more than 99% of the British male and female adult population would have to reach above shoulder height to put recyclables into the stillages.

11. When tipping the contents of the recycling box into a hopper, a two-handed tipping technique is a more suitable posture than a one-handed technique.

12. If access onto the vehicle is required when carrying a box, the stair design should be optimised to support this operation and reduce the risk of slips and trips.

13. The lugs situated on the side of the vehicle were generally used for supporting the box during sorting. However, not all crew members used the lugs, preferring instead to support the box with their body.

14. Generally, boxes were lifted using a two-handed technique in a stooped posture. The stooped posture results in slightly higher lower back compression when compared to a semi-squat posture.

15. Where a box is lifted or carried by grasping the edge of the box at a point closest to the body, an increased strain is placed on the wrists and forearms.

16. The observed and calculated lifting frequencies indicated that loaders are performing on average 1 or 2 lifts every minute.

17. There were occasions where the carry distance was greater than 10m but this is dependent upon the collection area and participation rates.

18. Carrying the box will restrict visibility and is likely to increase the risk of tripping and slipping due to the range of floor surfaces that crew members have to negotiate.

19. The evidence suggests that if suitable clothing is worn and there is regular access to drinking water there is minimal non-neutral thermal environmental effect on performing the task of lifting and carrying kerbside collection boxes.

Recommendations

1. Previous research suggests that the use of wheelie bins reduces the risk of manual handling injury compared to handling non-wheeled containers. Therefore, where possible it would be more appropriate to use wheeled bins for the collection of recyclables.

2. Where boxes are used, reduce the capacity of the boxes to at most 40 litres to provide a method of weight control. The maximum weight observed for a 40 litre box containing mixed glass and newspaper, including a lid, was 12.8 kg. This figure is below the level likely to exceed the NIOSH 3.4kN biomechanical criterion. Also, this weight is acceptable to at least 90% of the British male adult population.

3. The use of a lid would appear to be a practicable method of load control of the box reducing the occurrence of overfilling, and protecting the box contents from rainwater. However, there may be consequences for crew members in terms of removing the lid at collection. A more suitable lid, or alteration in the instructions given to residents may therefore be required.

4. The type of recyclable material collected at the roadside in the kerbside box will affect the weight potential of the box, and consideration needs to be given to this factor by the local authority in terms of their waste management system as a whole.

5. In order to reduce injury risks, crew members should use both handles of the boxes, i.e., they should engage in two-handed lifting, carrying and tipping.

6. Boxes with handholds separate from the rim are preferred as this encourages crew members to pick the box up using the handholds. To optimise the handholds the handhold dimensions should be in line with existing ergonomic recommendations.

7. Manufacturers should ensure that the rim of the box is wide enough and sturdy enough to allow it to be readily located onto the lugs of the vehicle rave rail.

8. The evidence suggests that weekly collections will result in lower weight lifts and a lower risk of injury for that particular lift. However, consideration should be given to the impact of the increased frequency of collection and exposure to a range of hazards. The impact of these risk factors is currently being researched by HSL with the outcome of the work being available in November 2006.

9. Local authorities and their contractors should provide instructions to residents on handling technique and the requirement to not overfill the boxes, and to leave the box for collection on a regular basis, even if the box is not full.

10. Crew members should avoid carrying boxes further than about 10m without resting. Irrespective of the distance carried, where boxes weigh approximately 13kg or more (see recommendation 2) crew members should divide the contents of the box and/or seek assistance from a work colleague before attempting to lift and carry the box to the vehicle.

11. Crew members should be given task specific training that is supported and encouraged by managers.

12. The vehicle design should take account of anthropometric measurements and aim to accommodate a high proportion of the population. Ideally, vehicles should be designed so that workers do not have to reach above shoulder height to empty or sort the contents of the kerbside box.

1 INTRODUCTION

This work was undertaken following a request from the Manufacturing Sector of the Health and Safety Executive to study manual handling in domestic recycling schemes where householders are provided with boxes to put out recyclable materials for collection. The work required the assessment of the risks of musculoskeletal disorders (MSDs) and the provision of recommendations to control the risks. The MSD risks to refuse collectors involved in the collection of refuse sacks and wheelie bins has been investigated previously (Pinder and Milnes, 2002; Pinder and Milnes, 2003). That work highlighted that wherever possible, refuse collection should be carried out using wheelie bins of appropriate sizes, with separate wheelie bins available for collection of recyclable materials. The evidence suggests the use of wheelie bins, instead of bags or small dustbins, will reduce the risk to refuse collectors of musculoskeletal disorders. Since the publication of the report, local authorities have increased the extent to which recyclable materials are collected from the household in order to meet recycling targets set out in the Waste Strategy 2000 report (DETR, 2000). One approach that many local authorities have adopted to help meet recycling targets is to use a kerbside box collection scheme.

The kerbside collection schemes generally require householders to separate recyclables from the residual waste stream, put them into a receptacle such as a box or bag, and place them at the boundary of their property or on the kerbside for collection. The type of collection systems range widely in terms of:

1. The types of recyclables accepted;
2. The frequency of collection;
3. The use of a dedicated vehicle that is either custom designed by the authority or 'off-the-shelf';
4. The extent to which sorting is carried out at the kerbside;
5. Participation rates of the households;
6. The type of houses and environment in which the refuse collectors operate;
7. The type of receptacle used for collection.

The implementation of kerbside box collection schemes, that require refuse collectors to lift and carry a box and potentially sort the contents at the vehicle, has potentially increased the risk of manual handling injuries. Manual handling injuries are the most frequently occurring injury in the waste management industry (BOMEL Limited, 2004), predominantly affecting those refuse/recycling workers who manually handle and sort waste. Therefore, an ergonomic investigation was deemed necessary in order to better understand the risks of MSDs associated with kerbside box collection schemes.

2 METHODS

2.1 INTRODUCTION

To assess the MSD risks in kerbside box collection of recyclables, three site visits were made to three different recycling operations situated in the South-West, Midlands, and North-East of England. The visits were undertaken in October and December 2005. During the site visits, video footage of the collection of recyclables was obtained along with weights and dimensions of the box containers, and dimensions of the vehicle. Further information pertaining to the round was obtained from the management personnel present and through informal conversation with the waste/recycling collectors.

2.2 DETAILS OF KERBSIDE COLLECTION SCHEMES STUDIED

Three different kerbside collection schemes were studied for this report. Each of the schemes is detailed below, with a summary given in Table 1.

2.2.1 Recycling Scheme 1

This is a local authority run kerbside collection recycling scheme that has recently been extended within the Borough. The scheme works by providing households with a green wheelie bin for recycling paper, card, cans, and plastics and a grey wheelie bin for residual refuse. The bins are each collected fortnightly on alternate weeks. A 55 litre capacity kerbside box is also supplied to households to be filled with glass only and is collected on a separate day to the wheelie bins on a bi-weekly basis. Where the scheme has not been introduced, the grey wheeled bin is collected on a weekly basis and recyclables including paper, glass and tins are collected on a bi-weekly basis with residents using plastic bags instead of boxes in which to leave the recyclables for collection. There is no kerbside sorting undertaken on the glass only collection rounds.

A three-person crew typically mans the rounds, with one crewmember driving and the other two collecting. Crewmembers will normally be collecting for 5/6 hrs a days, operating under a work system of ‘job and finish’ that allows crew members to go home once the round is completed.

2.2.2 Recycling Scheme 2

This kerbside collection recycling scheme is operated by a waste management organisation from the community sector. The original scheme included the collection of paper, glass, cans, textiles, shoes, and foil in a 55 litre capacity box on a bi-weekly basis. Yellow pages, batteries and engine oil are also collected. Residents are asked to keep different materials separate in the box, for example by using old carrier bags. A change to this recycling scheme has been introduced in a phased approach across the Borough with completion due in 2006. The scheme involves the additional weekly collection of food waste in a 25 litre capacity sealed bin alongside the box collection. A wheeled bin is also supplied for collection of general refuse, which is collected weekly under the old scheme and bi-weekly under the new scheme. The collection method requires crewmembers to sort the materials at the kerbside into separate stillages on the vehicle.

Either a two or three-person crew typically mans the recycling rounds. In the case of the two-person crew, both crewmembers will collect. In the three-person crew, typically one crewmember will drive and the other two collect; however, on occasions the driver will also collect. A typical day will start at 6.30 am and finish at 1.30 pm (scheduled to work until 3.30

pm) and can require a trip back to base to off-load and is usually where the crew members are able to take a 15-20 minute break. The system of work is operated on a ‘job and finish’ basis.

2.2.3 Recycling Scheme 3

This kerbside collection recycling scheme is operated by an independent waste management company. The scheme involves the collection of paper, glass, and cans in a 55 litre capacity box on a bi-weekly basis. A wheelie bin is provided for the collection of general refuse on a weekly basis. The materials collected on this round are sorted at the kerbside into hoppers on the side of the vehicle.

A three-person crew typically mans the round, with one crewmember driving and the others collecting. When needed, the driver will also undertake some collecting. The hours of work are either a 10 hr shift, working Monday to Thursday or an 8 hr shift working Monday to Friday. A typical day will start at 7.00 am (first load collected approximately 7.30 am) and finish between 2.30 and 4.00 pm. Crewmembers generally work for 4 to 5 hrs before returning to the depot to off-load where they will get a 1/2 hr break (excludes time spent driving to and from the depot). The crew will then return to the round and complete the collection. As in the previous schemes, the work organisation is on a ‘job and finish’ basis.

Table 1 Summary of the schemes studied

	Scheme 1	***Scheme 2***	***Scheme 3***
Type of round:	Bi-weekly collection of glass only. No sorting	Weekly collection of mixed recyclables. Contents sorted at kerbside.	Bi-weekly collection of mixed recyclables. Contents sorted at kerbside.
Box type	55 litre with separate handles	55 litre with separate handles plus a 25 litre bin for food waste.	55 litre 4-position shell handle (handles part of the rim)
Recyclables collected in the box/bin	Glass only	Paper, glass, cans, textiles, foil, and food waste	Paper, glass, and cans
Number in crew	3	2 or 3	3
Round duration	Approx. 5/6hrs	Approx. 7 hrs	Approx. 7.5 to 9 hrs
Recorded Observation time (mins)	16	35	42
Observation date	01/12/05	27/10/05	06/12/05

2.3 ASSESSMENT OF RECEPTACLE DESIGN

A variety of receptacles were collated from manufacturers, including both boxes and the bins seen on Recycling Scheme 2. To assess the influence of the receptacle design on the crewmember the dimensions and potential weights of the containers were recorded and compared with the recognised literature. The suitability of the handholds was also assessed.

2.3.1 Box weights and dimensions

To evaluate the potential weights of both the boxes and bins, the containers were loaded with glass only and a half and half mixture of glass and newspaper. These weights were measured under two conditions; one where a lid was fitted on top of the box or the box was only filled to the top edge and the other where the box was filled above the top edge. The weights of the boxes were recorded by placing the boxes on calibrated electronic scales.

During site visits to the three recycling schemes studied, weights of the kerbside boxes left for collection were obtained by going ahead of the crew and weighing the containers with the electronic scales or using a calibrated Mecmesin dynamometer and strap.

The dimensions of the boxes and bins, and the dimensions of the handholds on the receptacles were recorded and compared to the recommendations for tray design and tray handholds in (Chengalur *et al.*, 2004).

2.3.2 Effect of box design on manual handling risk

An assessment of the influence of the kerbside collection box design on manual handling risk was undertaken using a 3D biomechanical model (Chaffin, 1987; Chaffin and Erig, 1991) incorporated in a virtual human software package called 'JACK' (v5.0, UGS Corp, http://www.ugs.com). This calculates the potential compression forces of the L4/L5 intervertebral disc of the spinal column. High compressive forces acting on the lower back are known to increase the risk of injury. The US National Institute of Occupational Safety and Health (NIOSH) have recommended a maximum compressive force for the L5/S1 intervertebral disc of 3.4kN. The 3.4 kN limit defined the point at which they believed that the compression forces increased the risk of low-back injury (Waters *et al.*, 1993).

The analysis was performed using two different initial lifting postures, which were based on the observations of lifting techniques during the site visits. The first lifting posture was a stooped posture, with the back flexed and the legs and arms straight and the feet a short distance away from the box. The second posture was a semi-squat position with both the back and knees flexed to bring the centre of mass of the body closer to the ground. The elbows were also flexed and the feet were placed close to the box. A 50th percentile male (height: 175.49cm, weight: 77.69kg) and a 50th percentile female figure (height: 162.71cm, weight: 61.25kg,) were used for the assessment.

Each of the receptacles evaluated was created within the JACK software. The dimensions including the rim were used where the rim formed the handhold. Where receptacles had dedicated handholds, the dimensions excluding the rim were used. The virtual human was positioned at each box using the starting point of the two lifting techniques defined above. An initial box weight of 9 kg was used to reflect the average box weight observed in the recycling schemes studied, and the lower back compression reading taken. To assess the effect of a greater load, the box weights were increased by 1 kg increments until the biomechanical model indicated a compressive force of 3.4 kN.

The use of the NIOSH compression limit for the purposes of the evaluation offered a suitable method to define a cut-off point when examining how increasing the load or varying box dimensions affected spinal loading. However, there are known limitations in relation to the use of this figure as a risk threshold:

1. The epidemiological and biomechanical evidence which was used in setting the 3.4 kN limit has been shown to be inadequate and does not support its use as a threshold of elevated risk (Leamon, 1994; Jager and Luttmann, 1999)

2. The software system calculates the compression forces at the L4/L5 intervertebral disc, whereas the 3.4 kN limit refers to the compression forces at the L5/S1 intervertebral disc.

3. Compression forces are generally higher in males than females due to males being heavier and thus bearing more weight prior to lifting.

In this study, as the NIOSH compression limit is not being used to define the absolute level of risk associated with the load weight and receptacles, it is concluded that, despite the limitations outlined above, it is acceptable to use it as an appropriate cut-off point when examining the effect of variations in the parameters of a lifting task.

2.4 ASSESSMENT OF VEHICLE DESIGN

Three different types of vehicle design were assessed, two of which were observed in use on the recycling schemes studied. The third vehicle assessed was viewed on the 26th October 2005 in response to a specialist request. The dimensions of these three vehicles were recorded in a field notebook at the time of the visits. The dimensions of the vehicle are compared to anthropometric dimensions (Open Ergonomics Ltd., 2001)of the British male and female populations to ascertain what percentage of the population may be restricted or forced to assume an awkward posture as a result of the dimensions of the vehicle.

2.5 POSTURAL ANALYSIS

During the site visits to the three recycling schemes, video based observations of the crewmembers collecting and emptying kerbside boxes were recorded. To assess the risk of musculoskeletal injury, the Rapid Entire Body Assessment (REBA), (Hignett and McAtamney, 2000) technique was used to analyse the recorded postures of the crewmembers when loading the three types of vehicle. This tool was chosen because it incorporates dynamic as well as static postural loading factors, as well as the acceptability of the coupling with the load and the weight of the load.

The REBA postural analysis tool or MSD assessment tool uses a scoring system that gives an action level to indicate the urgency of workplace change. The body parts are divided into segments and a rating given according to the posture observed to give the total score. The action category levels are as follows:

Table 2 Action category levels for REBA

REBA score	***Risk level***	***Action***
1	Negligible	None necessary
2-3	Low	May be necessary
4-7	Medium	Necessary
8-10	High	Necessary soon
11-15	Very high	Necessary now

3 RESULTS

3.1 RECEPTACLE DESIGN

3.1.1 Weights of receptacles

When lifting a kerbside box, workers have to reach below knee height, at just over elbow distance away from the body. The guideline weights given by the L23 risk assessment filter (Health And Safety Executive, 2004) indicates a further assessment is required, when lifting a kerbside box, if weights exceed 7 kg for women and 10 kg for men. Table 3 summarises the weights of the receptacles observed during the three recycling schemes studied. The figures included in the table show the number of boxes that weigh over 7 and 10 kg.

Table 3 Summary of box weights observed on the three recycling schemes

	Scheme 1 – Bi-weekly collection	***Scheme 2 – Weekly collection***	***Scheme 3- Bi-weekly collection***
Round type and sample size	Glass collection only N = 27	Mixed recyclables including paper, glass and tins N = 22 (excludes food waste which is collected in separate containers)	Mixed recyclables including tins, glass, paper, and plastic N = 39
Mean box weight (kg)	9.88	8.06	11.38
Max. box weight (kg)	19.8	14.5	19.48
No. of boxes >7 kg	21 (78%)	18 (81%)	34 (87%)
No. of boxes >10 kg	12 (44%)	5 (22%)	23 (59%)

The range of weights observed in the recycling schemes is illustrated below in Figure 1. The results indicate that lower weights were observed in Scheme 2 where a collection is performed weekly. The highest weights observed were from Scheme 3, the mixed recyclables collected bi-weekly.

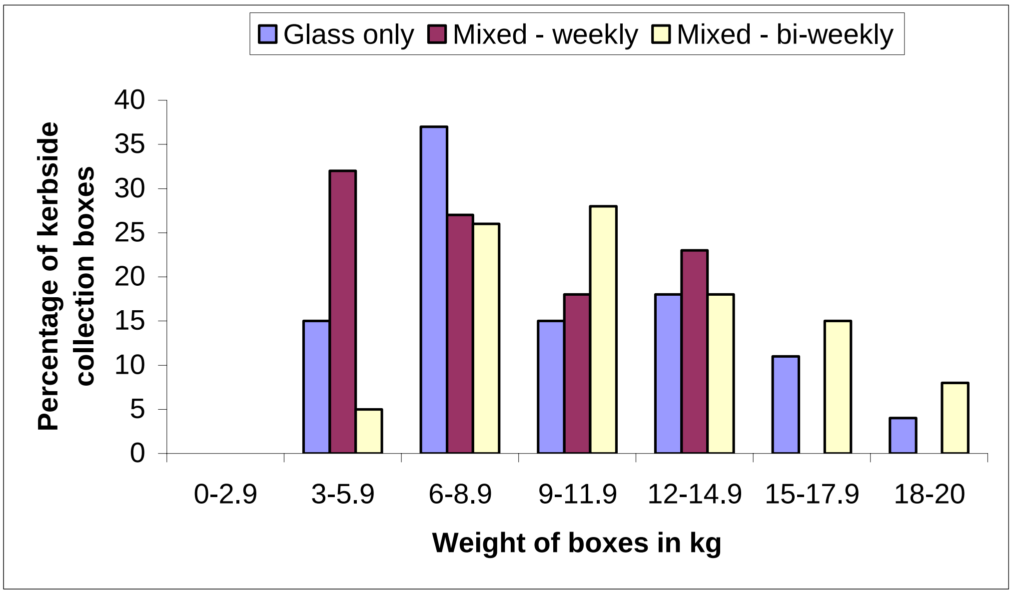

Figure 1 The percentage of weights recorded during observation of each recycling studied (box weight and contents combined)

The pictures in Figure 2 show the type of box contents that can be experienced on recycling collection schemes, and hence the difference between the maximum and average weights observed.

Figure 2 Observed contents of boxes

3.1.2 Dimensions of box style receptacles and influence on weight

The weights and dimensions of a range of different two-handed style receptacles were collected. Maximum weights were obtained for the receptacles when filled with glass only and a half and half mixture of glass and newspaper. The glass containers used consisted mostly of beer and wine bottles with a small number of jars. The beer bottles, jars and a single tabloid newspaper weighed in the region of 0.1 - 0.3 kg whilst the wine bottles weighed approximately 0.5kg each. The results are shown in Table 4 along with the relevant dimensions of the receptacles. Figure 3 illustrates the different types of box style receptacles assessed.

Table 4 Dimensions and weights of the receptacles examined

					Weights (kg) (lid weight = 0.6 kg unless stated otherwise)		
Box type	***Width (mm)***	***Length (mm)***	***Rim (mm)***	***Depth (mm)***	***Empty***	***Full (glass)***	***Full (mixed)***
1. 55 litre volume and 4 position shell handle	Top 430 max; 360 internal Base 300	Top 550 max; 480 internal Base 435	W 35 D 30	330	1.5	18.5 no lid 15 with lid	20.5 no lid 15.8 with lid
2. 55 litre volume and cut-out handles	Top 400 max; 370 internal Base 320	Top 520 max; 495 internal Base 450	W 12.5/15 (short/long sides) D 20	360	1.6	18.6 no lid 15.2 with lid	22.1 no lid 17.4 with lid
3. 55 litre volume and extended flange handles	Top 380 max; 350 internal Base 310	Top 520 external; 490 internal Base 445	W 15 D 20	375	1.1	18.7 no lid 14.7 with lid (lid weight 0.4)	21.3 no lid 16.5 with lid (lid weight 0.4)
4. 44 litre volume and 4 position shell handle	Top 430 max; 360 internal Base 250	Top 550 max; 480 internal Base 375	W 35 D 30	310	1.4	12.8 no lid 10.5 with lid	19 no lid 14.2 with lid
5. 44 litre volume with handles	Top 390 max; 360 internal Base 320	Top 520 max; 495 internal Base 450	W 12.5 /15 (short/long sides) D 20	280	1.4	14.4 no lid 11.9 with lid	19 no lid 14.3 with lid
6. 40 litre continuous grab rim – flat side	Top 370 max; 345 internal Base 325	Top 520 max; 495 internal Base 465	W 12.5 D 20	265	1.4	14.3 no lid 11.9 with lid	17.4 no lid 12.8 with lid
7. 38 litre volume and extended flange handles	Top 380 max; 350 internal Base 310	Top 520 max; 490 internal Base 445	W 15 D 20	275	1.1	14 no lid 10.7 with lid (lid weight 0.4)	15.9 no lid 11.9 with lid (lid weight 0.4)
8. 33 litre volume basket, solid side	Top 300 max; 260 internal Base 210	Top 490 max; 400 internal. Base 420 rear, 350 front		385	1.3 kg	12.1 overfilled; 9.0 to brim	13.9 overfilled; 10.8 to brim
9. 33 litre volume basket, lattice side	Top 285 max; 230 internal Base 210	Top 490 max; 400 internal. Base 410 rear, 345 front		385	0.9 kg	11.7 overfilled; 8.6 to brim	11.4 overfilled; 8.6 to brim

Box type 1 & 4: 4-position shell handle

Box type 2 & 5: flange extension cut-out handles

Box type 3 & 7: extended flange handles

Box type 6: continuous grab rim

Box type 8: solid side basket

Box type 9: lattice side basket

Figure 3 The range of box receptacles assessed

The maximum weight observed in the laboratory for the 55 litre boxes when filled with glass only (18.5 kg) was less than that observed during Recycling Scheme 1 (19.8 kg). This is likely to be due to differences in weights of individual glass bottles and therefore how tightly the box was loaded. The maximum mixed recyclable weights for the 55 litre boxes were higher under laboratory conditions than those observed in the recycling schemes studied. In all but one case the mixed recyclables maximum weights observed were higher than for glass only. This corresponds with the observations made of the recycling schemes whereby the bi-weekly mixed recyclable collection resulted in more boxes weighing above 15 kg than the bi-weekly glass only collection.

The maximum weights measured in the laboratory, for box types 1 to 7 were under two conditions, one where the box was filled to its maximum whilst still being able to put a lid on and the other where the box was filled as full as possible. In the case of box types 8 & 9, the boxes were filled to the brim with no lid used (none were available for these types of box) and filled as full as possible. The maximum weight difference observed between the lid and no lid conditions for box types 1 to 7 was 4.8 kg, with the mean being 3.9 kg (n = 12).

Three of the box types studied had two capacity options. Box types 1 & 4 and 2 & 5 are manufactured as either 55 litre or 44 litre capacity boxes, whilst box types 3 & 7 are manufactured as either 55 litre or 38 litre capacity boxes. Box types 1 & 4 differ slightly in all dimensions, whilst box types 2 & 5 and 3 & 7 differ mostly by depth.

Container design influences the amount of weight that is acceptable to lift to the majority of the population. Guidelines for tray design that address the configuration and size of the container are provided by Chengalur *et al.* (2004). The guidelines for tray design are as follows:

Tray width for containers with handholds:
- Recommended maximum of 360 mm
- Upper limit of 510 mm.

This dimension determines how far away the centre of mass of the load is in front of the handler's lumbar spine. The greater the width, the greater the horizontal distance becomes, resulting in increased stress on the spine and shifting the load from the stronger elbow flexor muscles in the upper arms to the muscles acting across the hands, wrists and shoulders. Using the largest measurements that include the rim, only box types 8 & 9 satisfy the recommendations for this dimension but all fall below the suggested upper limit. The greatest deviation from the recommendation is 70 mm.

Tray length for containers with handholds:
- Recommended maximum of 480 mm
- Upper limit of 610 mm.

This dimension affects whether the tray can be held without abducting the shoulders. With the arms abducted, the load falls more on the shoulder muscles such as the deltoid, which are weaker than the arm muscles such as biceps brachii. Using the maximum measurements that include the rim, none of the boxes assessed satisfy this recommendation but all fall below the suggested upper limit. The greatest deviation from the recommendation is 50 mm.

Tray depth:
- ≤ 130 mm

A deep tray or container is more likely than a shallow one to interfere with walking when being carried, and the deeper the tray, the greater the requirement to hold the tray away from the body and higher to reduce interference (Chengalur *et al.*, 2004). This will increase the horizontal distance, thus increasing the stress placed on the spine, hand, wrist and shoulders. All of the boxes assessed exceeded this recommendation with the greatest deviation being 255 mm.

3.1.3 Dimensions of 'bin' style receptacles and influence on weight

The 25 litre 'bin' style of receptacle (Figure 4) was used in Scheme 2 for the purposes of collecting food waste. These bins have a drop down handle and a hinged lid, and can be carried using the handle to the side of the body. Both 25 litre and 35 litre capacity 'bins' were assessed.

Figure 4 Illustration of the 'bin' used to collect food waste in Scheme 2

The dimensions and weights of the bins are shown in Table 5. The observed maximum weight when using the 25 litre bin on Scheme 2, where the bin was filled with food waste, was 11.7 kg. This is greater than the weights observed in the laboratory when the bin was filled with glass only and mixed recyclables. The lower maximum weight observed with glass and mixed recyclables is likely to be due to the air voids within and between glass items. Consequently, the user can put more food waste into the container, which leads to an increase in weight.

Table 5 Dimensions and weights of the bins examined

Box type	***Dimensions***			***Weights***		
	Width mm (external)	***Depth mm***	***Length mm (external)***	***Empty kg***	***Full glass kg***	***Full mixed kg***
1. 25 litre capacity tall bin with handle	270 Top 230 Base	440	270 Top 220 Base	1.3 kg	8.9 lid open 7.4 lid closed	9.5 lid open 7.1 lid closed
2. 35 litre capacity tall bin with handle	270 Top 230 Base	485	350 Top 290 Base	2.0 kg	11.7 lid open 9.5 lid closed	14.8 lid open 12.4 lid closed

3.1.4 Coupling with the receptacle – box style receptacles

The design of handles on the receptacles will affect the coupling with the container, which in turn affects the acceptable weight of the load to be lifted and carried. Chengalur *et al.* (2004) recommended dimensions for four types of handhold for carrying trays: handhold cut-out, gripping block, contoured gripping block, and drawer pull. Four other types of handhold are identified as less satisfactory: rolled edge, rim, overhang, and ledge. In Figure 5, handholds ‘b, and f’ are classified as being most suited with handholds ‘c, and d’ classified as being least suited. Handles that are least suited tend to cause high pressure on the fingers due to the lip of the rim bearing down into the hand with the weight then being taken on the fingertips.

Chengalur *et al.*, (2004) also defined recommended dimensions for a one-handed handhold and in Figure 5 this represents handholds ‘a’ and ‘e’. Handhold ‘a’ is a combination of a drawer pull, cutout and one-handed handhold. However, for the purpose of this assessment it has been classed as a one-handed handhold so the diameter of the handle could be compared with the recommendations given for the one-handed handhold.

a. Box types 2 & 5

b. Box types 3 & 7

c. Box type 6

Extension of container flange: a) with a cut-out handle, b) with a solid longitudinal and lateral extension handle (drawer pull) and c) lateral extension handle (overhang)

d. Box types 1 & 4

Reduction of container flange (overhang)

e. Box types 8 & 9

Attached loop with grip block (one-handed handle)

f. Box types 8 & 9

Integral cut-out handhold (cut-out handle)

Figure 5 The handholds on the assessed ‘box’ style receptacles

The dimensions of the handles are shown in

Table 6. Recommended dimensions for handholds on trays (Chengalur *et al.*, 2004) are as follows:

Handhold cut-out (Figure 6):

- o Length 114 mm or 139 mm if gloves are worn
- o Height 32 mm or 57 mm if gloves are worn
- o Handle depth 10 mm

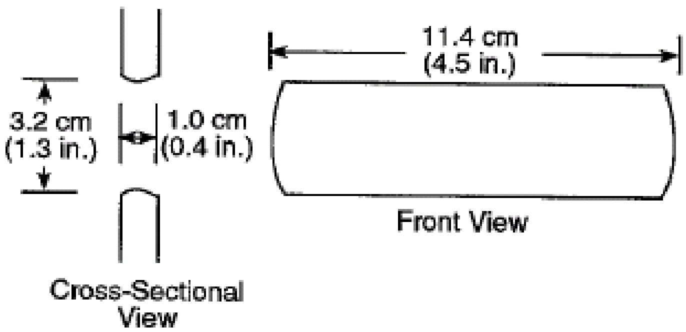

Figure 6 Diagram of the recommended dimensions of a handhold cutout (diagram cited in Chengalur *et al*., 2004)

Box types 8 & 9, which both have cut out handholds, meet the recommendations on the width but not on the height or depth of handle.

Drawer pull (Figure 7):

- Width of clearance between handle and box is 32 mm or 42 mm if gloves are worn
- Width of handle 10 mm
- Depth of handhold 70 mm

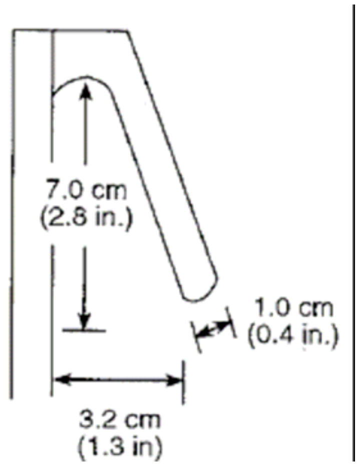

Figure 7 Diagram of the recommended dimensions of a drawer pull handout (diagram cited in Chengalur *et al*., 2004)

Box types 3 & 7, which both have drawer pull style handholds, do not meet the recommendations.

One handed handles (Figure 8):

- Width of handle 120 mm or 145 mm if gloves are worn, and 240 mm if two hands are used or 265 mm if wearing gloves and using two hands
- Width of clearance between handle and box 64 mm or 89 mm if gloves are worn,
- Diameter of handle min. 19 mm for an object > 9 kg, and max. 38 mm

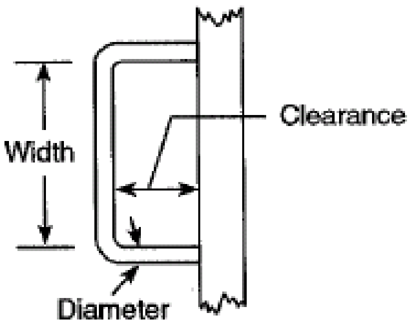

Figure 8 Diagram of the one-handed style handhold (diagram cited in Chengalur *et al*., 2004)

Box types 8 & 9, which both have a one-handed handhold, do not meet the recommendations on the handle width or diameter. Box types 2 & 5, which have been classed as a one-handed handhold for the purpose of comparing the dimension of the handle meet the recommendations on all but the clearance width.

Table 6 Dimensions of the handles on the kerbside collection receptacles

No.	***Container type***	***Handhold***					
		Type	***Length (mm)***	***Depth (mm)***	***Width (mm)***	***Thickness handle/lip (mm)***	***Distance between handles (mm)***
1.	55 litre capacity with 4 position shell handle	d.	140	25	35	5	550
2.	55 litre capacity with handles	a.	150*	\	25** 25***	15	590 320 handle height
3.	55 litre capacity with extended flange handles	b.	120	45	20** 30***	30	585 335 handle height
4.	44 litre capacity with 4 position shell handle	d.	140	25	35	5	550
5.	44 litre capacity with handles	a.	150*	\	25** 25***	15	590 250 handle height
6.	40 litre continuous grab rim – flat side	c.	130	20	17	5	520
7.	38 litre capacity with extended flange handles	b.	120	45	20** 30***	30	585 240 handle height
8. & 9.	33 litre capacity basket, solid side & lattice side	e.	115*	\	160** 10***	\	\ 550 handle height
		f.	92*	25 (rim)	62 (height)	10	490

Key:
Handhold length – length of the handhold (described as width in Chengular et al., 2004)*
Handhold depth – flange depth including handle
*Handhold width – flange width/ clearance between handle and box**/width or diameter of handle****
Thickness of handle/lip – Depth of handle/rim thickness
Handle height – indicated where the height of the handles is different to the height of the box

3.1.5 Coupling with 'bin' style receptacle

The handles used on the 'bin' style receptacle are attached and designed for one-handed carrying. These handles are illustrated in Figure 9 below.

g. Bin type 1 (25 litre capacity)

h. Bin type 2 (35 litre capacity)

Figure 9 Handles on the 'bin' style receptacle

The dimensions of the handles are shown in Table 7. Comparing the dimensions to the recommendations for one-handed handles in Section 3.1.4 (Chengalur *et al.*, 2004), these handles meet all the requirements.

Table 7 Dimensions of the bin style attached handholds

No.	***Container type***	***Handle***					
		Type	***Handle width (mm)***	***Depth (mm)***	***Width (mm)***	***Handle height (mm)***	***Clearance (mm)***
1.	25 litre capacity tall bin with handle	g.	300	13	20	230 630 incl. bin	180
2.	35 litre capacity tall bin with handle	h.	380	13	25	270 730 incl. bin	240

Key:
Handle width – Total width of handle across bin
Depth – Depth of handle crosssection
Width – Width of handle crosssection

3.1.6 Effect of different box dimensions on lower back compression

The low back compression forces of the L4/L5 intervertebral disc were obtained to assess the effects of lifting kerbside collection boxes of different dimensions. The compression forces were estimated using a biomechanical model incorporated in a software package called JACK (v5.0, UGS Corp, http://www.ugs.com). Two types of lifting activity were simulated, based upon the techniques observed during the site visits (see Section 3.3.1). These are illustrated below in Figure 10 and Figure 11. Box types 8 and 9 were not included in the assessment, as these types were not observed in use on the collection schemes studied. The results of the assessment are given in Table 8 and Table 9.

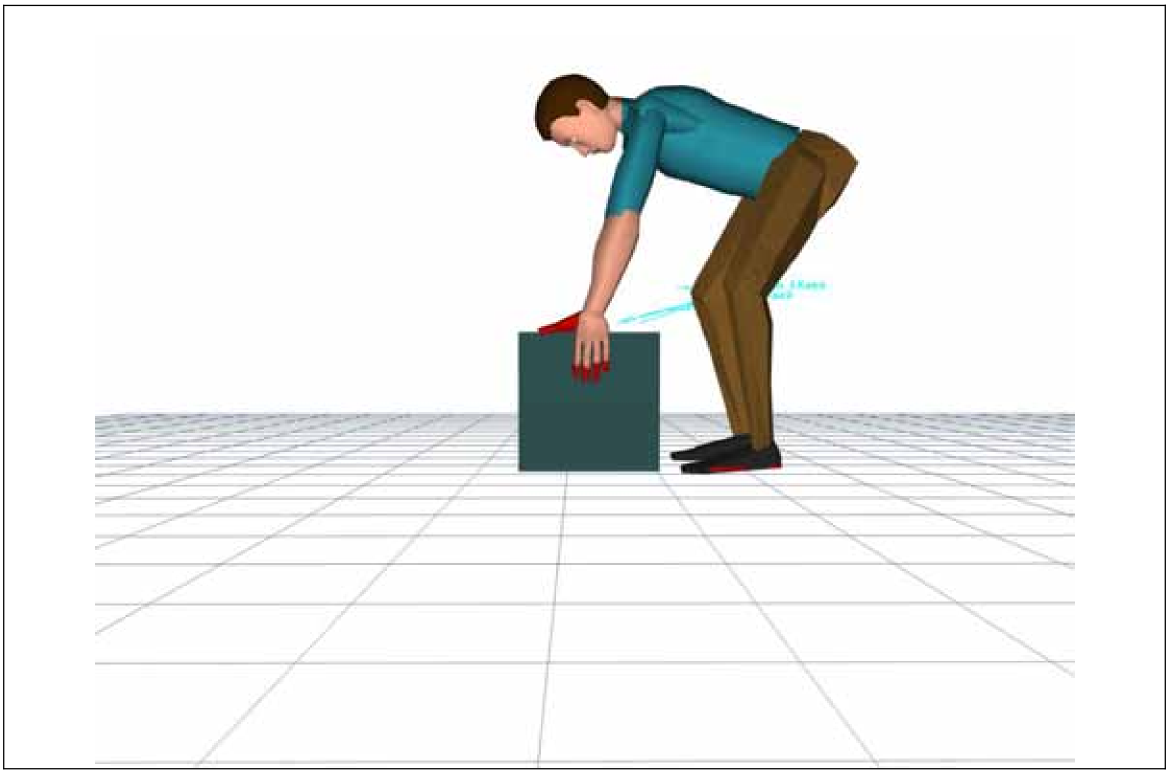

Figure 10 Stooped position lifting technique

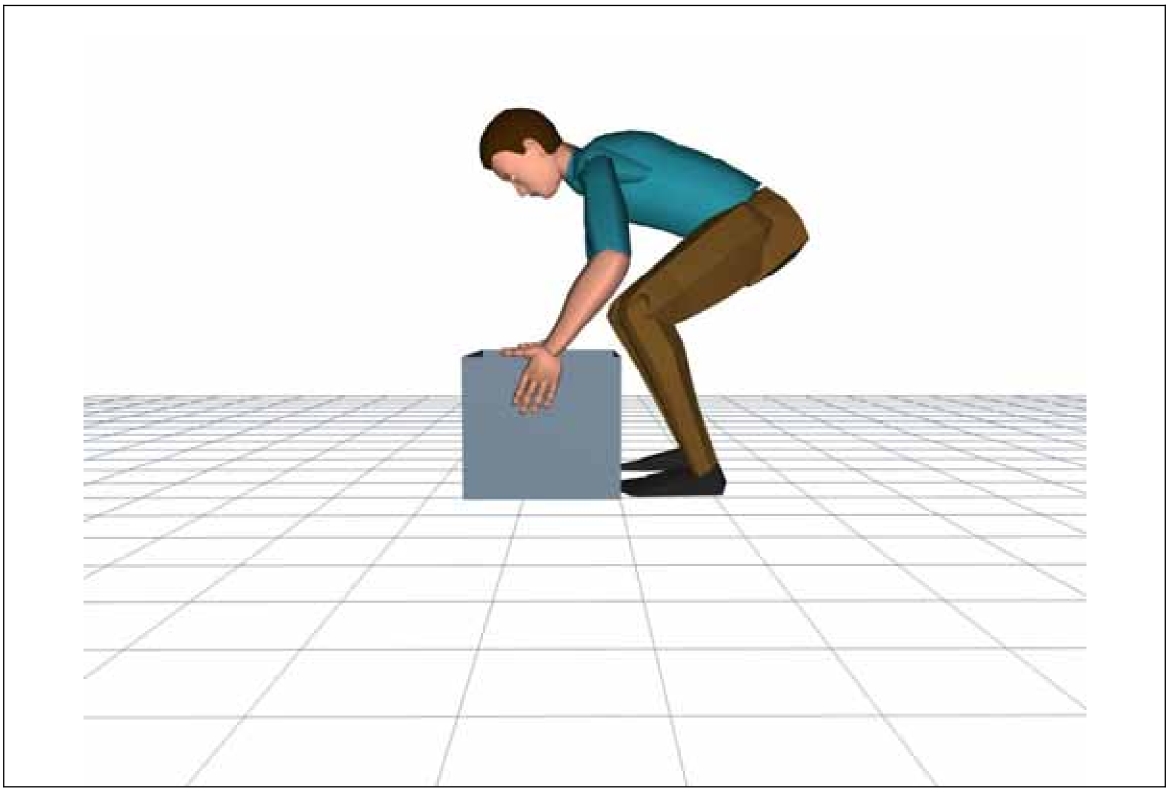

Figure 11 Semi-squat position lifting technique

Table 8 Low back compression forces (kN) occurring at the L4/L5 vertebral disc at the start of a lift adopting a stooped posture

	Weight of boxes									
	9 kg		*10 kg*		*11kg*		*12 kg*		*13 kg*	
Box type	***M (kN)***	***F (kN)***	***M (kN)***	***F (kN)***	***M (kN)***	***F (kN)***	***M (kN)***	***F (kN)***	***M (kN)***	***F (kN)***
1. 55 litres	3.14	2.18	3.24	2.25	3.33	2.32	3.43	2.39	/	/
2. 55 litres	3.10	2.14	3.20	2.21	3.29	2.28	3.38	2.35	3.47**	2.42**
3. 55 litres	3.05*	2.11*	3.14*	2.17*	3.23*	2.24*	3.32	2.30*	3.40	2.37*
4. 44 litres	3.16**	2.20**	3.25**	2.27**	3.35**	2.34**	3.44**	2.41**	/	/
5. 44 litres	3.15	2.17	3.24	2.23	3.33	2.30	3.42	2.36	/	/
6. 40 litres	3.08	2.13	3.15	2.20	3.23	2.26	3.32	2.32	3.45	2.39
7. 38 litres	3.06	2.16	3.15	2.22	3.23	2.29	3.32*	2.35	3.40*	2.42

Key: * *lowest compression force observed for a given box weight*
** *highest compression force observed for a given box weight*

Table 9 Low back compression forces (N) occurring at the L4/L5 vertebral disc at the start of a lift adopting a semi-squat posture

	Weight of boxes									
	9 kg		*10 kg*		*11 kg*		*12 kg*		*13 kg*	
Box type	***M (kN)***	***F (kN)***	***M (kN)***	***F (kN)***	***M (kN)***	***F (kN)***	***M (kN)***	***F (kN)***	***M (kN)***	***F (kN)***
1. 55 litres	2.89	2.31	2.97	2.40	3.06	2.49	3.14	2.57	3.23	2.66
2. 55 litres	2.93	2.29	3.02	2.38	3.11	2.46	3.20	2.55	3.29	2.64
3. 55 litres	2.92	2.25*	3.01	2.34*	3.10	2.42*	3.19	2.50*	3.27	2.58*
4. 44 litres	2.99**	2.33**	3.08**	2.42**	3.17**	2.50**	3.25**	2.59**	3.34**	2.68**
5. 44 litres	2.94	2.31	3.03	2.40	3.12	2.48	3.20	2.56	3.29	2.64
6. 40 litres	2.87*	2.29	2.95*	2.37	3.03*	2.44	3.12*	2.52	3.20*	2.60
7. 38 litres	2.96	2.29	3.04	2.38	3.13	2.46	3.22	2.54	3.30	2.62

Key: * *lowest compression force observed for a given box weight*
** *highest compression force observed for a given box weight*

The results of the analysis show there is no more than 5% difference between the lowest and highest compression forces for both males and females. The highest compression force observed was for box type 4 for both male and females for all box weights. However, due to the small differences observed in low back compression it is unlikely that the differences in the dimensions of the boxes studied are great enough to significantly increase the risk of injury in biomechanical terms.

Low back compressions were only taken up to the 3.4 kN limit for the male stooped posture. The load limit was reached first by box types 1, 4 & 5 at 12 kg and then box types 2, 3, 6 & 7 at 13 kg. According to NIOSH (Waters *et al.*, 1993), exceeding the 3.4 kN value is likely to increase the risk of injury. Therefore, this suggests that a load of 12 to 13 kg should not be exceeded in order to control the risk of injury when lifting using a stooped posture. The results for the squat position male lower back compression, up to a 13 kg load, did not exceed the 3.4 kN limit. Whilst it would seem advantageous to train individuals to lift using a squat position, in practice workers are unlikely to do this all of the time, due to it being quicker and less energetically demanding to lift from a more stooped posture (Garg and Herrin, 1979; Welbergen *et al.*, 1991; Straker, 2003). The squat posture observed seemed to be used for heavier boxes.

The compression results for females were less than for males because of the difference in physical weight affecting the un-loaded compression forces on the spine. The 3.4 kN maximum compression force is of limited use when considering females because they are not able to withstand the same compression forces as for men (Jager and Luttmann, 1996).

3.2 VEHICLE DESIGN

Three different types of vehicle were assessed for the purposes of this study. One vehicle was loaded using side hoppers, and once full they were mechanically lifted via hydraulics and emptied into stillages contained within the vehicle. With the other two types of vehicle, the recyclables were loaded directly into the stillages. Of these vehicles, one required the recyclables to be loaded into stillages inside the lorry, with no loading done on the kerbside. The other could be loaded from both the kerbside and the lorry.

3.2.1 Dimensions and design of vehicles

Vehicle 1 – This vehicle has side-loading hoppers (Figure 12), which crewmembers fill with recyclables. Either these are sorted at the kerbside, with the box resting on lugs situated just above the edge of the hopper, or the box contents are tipped directly into the hopper (Figure 13). The partitions within the hopper can be adjusted to suit requirements. The loading edge of the hopper is known as the 'rave-rail', and whilst the hoppers are manufactured to be the same size, the height of the rave-rail when on the vehicle may vary depending on the type of vehicle used.

Figure 12 The hoppers on vehicle 1 in the loading position and in a raised position, tipping the contents into the stillages within the vehicle

Figure 13 A box resting on the lugs of the hopper and the contents of a box being tipped into the hopper

The rave-rail height of the hoppers close to the ground, in the vehicle observed, was measured as 1060 mm, and 1510 mm for the hopper above the wheel arch. The height of the lugs on the hopper to the floor was 1090 mm. Accounting for a 30 mm shoe height, the height of the 1060 mm hopper plus the additional 30 mm for the lug height, will be below standing elbow height for approximately 80% (Open Ergonomics Ltd., 2001) of the British male adult (BMA) population. This figure is reduced to approximately 20% for the British female adult population (BFA). Therefore approximately 80% of BFA, and 20% of BMA will have to reach above standing elbow height to lift the box onto the hopper lugs.

To load the hopper above the wheel arch, at a height of 1510 mm, would result in 67% of the BMA population and 99% of the BFA population reaching above shoulder height.

These figures are based upon the crewmember standing at the same height as the lorry. It is likely that the lifting and sorting of the boxes will often be performed with the crewmember standing on the pavement. Standard kerb heights are between 125 and 150 mm, so in these circumstances the number of people who would have to reach above standing elbow height to lift the box onto the hopper lugs and reach above shoulder height to load the hopper above the wheel arch would be reduced.

Vehicle 2 – This vehicle is loaded via stillages that are situated within the lorry. The vehicle is not designed for any kerbside loading. The method of work generally used requires one crewmember to remain in the lorry with one or two other crewmembers lifting the boxes up onto the lorry. Before the contents are sorted it has to be lifted to shoulder height to clear the stillage. The vehicle dimensions are illustrated in Figure 14.

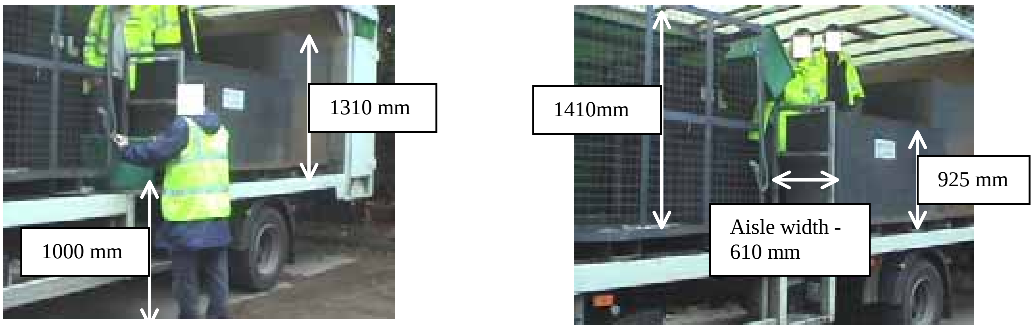

Figure 14 Diagram to show the dimensions of vehicle 2

The percentage values of the British male and female adult population who would have to reach above shoulder or elbow height to throw recyclables into the stillages are shown in Table 10. The stillage at 925 mm high is used to rest the box in for sorting purposes. In order to place the box within the stillage it has to be lifted over the side. Therefore the box height has been added to the height of the stillage.

The width of the aisle on the lorry is 610 mm. The length of the box is 500 mm, and from handhold to handhold the distance is approximately 570 mm. Therefore, given a hand depth of 61mm (50^{th} percentile) for BMA and 51mm (50^{th} percentile) for BFA (Open Ergonomics Ltd., 2001), there would not be enough room to keep the hands on the handles, when the box is placed lengthways into the lorry. These restrictions on space result in the crewmember being forced to twist and turn to pick up the box from floor level.

The bed height of the lorry is 1000 mm. To lift the recycling container onto the bed using the box handles would result in 25% of the BFA population reaching above shoulder height. For the BMA population this figure is 0.5%.

Table 10 The percentage of British male and female adults who would have to reach above shoulder height or elbow height to put recyclables into the stillages of vehicle 2

Stillage height (mm)	*Approximate % of population that would need to reach above shoulder height (accounting for 30 mm in shoe height)**	*Approximate % of population that would need to reach above elbow height (accounting for 30 mm in shoe height)**
925	<0.01% of BMA <0.01% of BFA	<0.01% of BMA 3% of BFA
925 + box height of 350	0.08% of BMA 8% of BFA	99.5% of BMA >99.9% of BFA
1310	0.4% of BMA 20.5% of BFA	99.9% of BMA >99.9% of BFA
1410	13.7% of BMA 79.4% of BFA	>99.9% of BFA >99.9% of BMA

**Note: The anthropometric data are taken from PeopleSize licensed software (Open Ergonomics Ltd, 2001)*

Vehicle 3 – This vehicle is loaded via stillages situated within the lorry. However, there is access to the stillages from the kerbside due to the use of ‘drop-down’ flaps that can be closed up when the contents of the stillage reach the level of the flap. Loading can then continue on the lorry. Some of the stillages used do not have ‘drop-down’ flaps that face the kerbside so entry into the vehicle is required to load the stillage.

Figure 15 Diagrams to show the dimensions of vehicle 3

The figures in Table 11 show the percentage of British male and female adults who would have to reach above shoulder height to load recyclables into the stillages. More than a third of the BFA population would have to reach above shoulder height for the lowest stillage loading and increases to more than 99% for stillages higher than 1510 mm. Comparatively, only when the stillage height is at 1510 mm does more than 50% of the BMA population have to reach above shoulder height.

Table 11 The percentage of British male and female adults who would have to reach above shoulder height to put recyclables into the stillages of vehicle 3

Stillage dimension	***Vehicle***	***Height (mm)***	***Approximate % of population that would need to reach above shoulder height (accounting for 30 mm in shoe height)****
Exterior lower stillage height	7.5 T	1360 mm	3% of BMA 50.1% of BFA
	12 T	1340 mm	1.5% of BMA 36.8% of BFA
Exterior upper stillage height	7.5 T	1780 mm	>99.9% of BMA >99.9% of BFA
	12 T	1800 mm	>99.9% of BMA >99.9% of BFA
Interior stillage	7.5 T	1510 mm	67.4% of BMA 99.2% of BFA
	7.5 T and 12 T	1270 mm	0.07% of BMA 6.9% of BFA
Interior stillage open flap	12 T	1300 mm	0.3% of BMA 15.9% of BFA
Interior stillage closed flap	12 T	1590 mm	95.5% of BMA >99.9% of BFA

**Note: The anthropometric data are taken from PeopleSize licensed software (Open Ergonomics Ltd, 2001)*

The stair width of the 12T vehicle is 950 mm. There is approximately a 590 mm distance between the handholds of a 55 litre capacity box with handles. Therefore, when climbing into the vehicle there is enough space available for the crewmember to able to retain hold of the handles. However, the width of the aisle at 645 mm for the 7.5T vehicle and 625 mm for the 12T would not allow a crewmember to hold the box using the handles in the intended manner. Therefore, to retain hold of the box using the handholds, crew members are required to position themselves sideways on to enter the aisle. Alternatively, the box is held using the rim instead of the handholds.

3.2.2 Postures adopted when loading on different types of vehicle

To give a quantitative assessment of the postures adopted when crewmembers were sorting or tipping onto the lorry, REBA postural analysis was used.

Vehicle 1 – When tipping the contents of the box into the hopper, three different techniques were observed. One involved the worker lifting the box to shoulder height and turning the box over in a fluid motion. The second technique was to rest the box on the rim of the hopper, using the rim as a fulcrum to tip the box. The third technique was to tip the contents sideways into the hopper, holding the box with one hand and using the side and front edge of the hopper to support the box. These techniques are illustrated in Figure 16 and Figure 17 below.

2-handed tip resting the box on the side of hopper

2-handed tip without resting the box on the side of the hopper

Figure 16 Postures adopted when off-loading boxes on vehicle 1

One-handed box tipping

2-handed tip into the hopper above the wheel arch

Figure 17 Postures adopted when off-loading boxes on vehicle 1

The results of the REBA assessment are shown in Table 12. The potential weight of the load for each technique was taken to be greater than 10 kg because the tipping of contents observed on Recycling Scheme 1, the glass only round, involved 44% of weights being greater than 10 kg. The one handed tipping shown in Figure 17 was actually seen on Recycling Scheme 3, where most of the contents will have been sorted individually prior to tipping the remaining contents. In order to show the influence of the difference in technique on the assessment of risk, the results for 1-handed tipping show the score for a load/force greater than 10 kg and a load/force less than 5 kg. The results show that despite using a greater weight factor in the 2-handed tipping compared to the 1-handed technique, the REBA score is less because the trunk remains straight.

Table 12 Results of REBA assessment for vehicle 1

Activity	*REBA score*	*Risk level*	*High scoring segments*
2-handed tip resting box on side of hopper	3	Low	Potential load/force
2-handed tip without resting box on the side of hopper	6	Medium	Potential load/force combined with position of upper arm
1-handed tip resting box on the side of hopper >10 kg	9	High	Flexing trunk to the side, potential load/force combined with position of upper & lower arm including the wrist.
1-handed tip resting box on the side of hopper <5 kg	7	Medium	Flexing the trunk to the side, combined with position of the upper & lower arm including the wrist.
2-handed tip into the hopper above the wheel arch >10 kg	9	High	Lifting the load above shoulder height, which results in having to twist, flex and extend the neck.

Vehicle 2 – The technique of off-loading the contents of the boxes observed on vehicle 2 was to have one crew-member remain permanently within the lorry (when it was stationery) emptying the contents into the stillages, whilst the other 1 or 2 crew members would lift and carry the boxes to place them on the lorry. This technique is illustrated in Figure 18.

Placing box on vehicle bed

Lifting box off the floor

Lifting box over stillage

Figure 18 Method of passing box to crewmember on vehicle 2 and then lifting box ready to sort

Table 13 shows the results of the REBA assessment for the work technique used on vehicle 2. The weights of the box loads that are encountered on recycling schemes using this vehicle are unknown. However, taking the weights observed in the three recycling rounds studied indicates there will be a percentage of boxes that weigh over 10 kg. Therefore, taking the worst-case scenario, a potential load of 10 kg or more was used to calculate the REBA score.

Table 13 Results of REBA assessment for vehicle 2

Activity	*REBA score*	*Risk level*	*High scoring segments*
Placing box on vehicle bed	6	Medium	Load/force combined with outstretched arms and a poorer coupling with the box.
Lifting box off the floor	10	High	Degree of flexion and twist in trunk. Load/force combined with upper & lower arm position.
Lifting box over stillage	10	High	Flexing trunk to the side, load/force combined with position of upper & lower arm

The assessment indicates that handling the box within the vehicle has a high risk potential due to the constraints placed on the workers posture by the vehicle design. The constraints result in the crew member having to twist, turn and lift the load off the floor and over the stillage in order to begin off-loading the contents.

Vehicle 3 – This vehicle was used for collection purposes in Recycling Scheme 2 where full sorting of the contents of the boxes was undertaken (i.e. separating different coloured glass, paper, tins and textiles). This method produces a greater number of postures adopted by the crewmembers because of the facility to off-load both on the kerbside and in the vehicle. The types of postures observed are shown in Figure 19 to Figure 21.

Extended reach to tip contents of box

Tipping food waste into stillage

Figure 19 Tipping contents of box directly into the stillage

Bending to sort contents of box on kerbside

Bending to sort contents of box on the lorry

Figure 20 Bending to sort through the contents of the box

Throwing recyclables into top stillage flap

Lifting box over stillages inside the vehicle

Figure 21 Sorting recyclables both inside and outside the lorry

The results of the REBA assessment are shown in Table 14. The load weight for tipping the box contents was taken to be between 5-10 kg. This range was taken to reflect a potential maximum figure for a box that has been partially emptied via sorting prior to tipping the remaining contents.

The higher scores of 7 & 8 are a consequence of the requirement to reach above shoulder height and/or twist the trunk to either tip out the contents of the box or throw items individually into the stillages. Even when the load is negligible, continually reaching above shoulder height increases the strain on the muscles, thus resulting in a higher score.

The bending to sort the contents of the box on the lorry floor appeared to be an alternative method to taking the box up the narrow aisle and then having to lift the box over the stillages in order to retreat.

An additional factor when tipping the contents of the food waste bin is the requirement to shake the bin in order to remove the waste that is stuck. This will place additional stress upon the spine and shoulders due to shaking the bin above shoulder height.

Table 14 Results of REBA assessment for vehicle 3

Activity	*REBA Score*	*Risk Level*	*High scoring segments*
Extended reach to tip contents of box	7	Medium	Extended reach above shoulder height
Tipping food waste into stillage	8	High	Twist in the trunk with extended reach above shoulder height.
Bending to sort contents of box on kerbside	1	Negligible	
Bending to sort contents of box on the lorry	5	Medium	Degree of flexion in trunk combined with extension of arms to reach down into the box.
Reaching up to throw recyclables into the stillage from the roadside	7	Medium	Reaching above shoulder height to throw contents into the stillage that also results in neck extension.
Lifting box over stillages inside the vehicle	8	High	Reaching above shoulder height, with the back and neck in extension.

3.2.3 Access / egress issues

Figure 22 shows the means of access and egress from vehicles 2 and 3. In the case of vehicle 2, access to the vehicle is required to allow one crewmember to sort on the vehicle. At the time of access or egress the crewmember would not be carrying a box. Comparatively, all crewmembers of vehicle 3 require access and egress to the vehicle on a frequent basis to sort the contents of the boxes. To do this boxes are carried up and down the stairs of the vehicle. Therefore, the stairs on vehicle 2 have different functional requirements to those on vehicle 3.

Vehicle 2 – access/egress

Vehicle 3 – access/egress

Figure 22 Access / egress issues

There is no British Standard available for access to road vehicles of this type, however, there is a British Standard for stairs, ladders and walkways (BSI, 1985; BSI, 2000) that can be referred to for design purposes. For the design of stairs, the standards state that the 'going' and the 'rise' (indicated in Figure 22) should be consistent for safety and user confidence. In the case of a public stair, the rise should be between 100mm and 190mm, and the going between 250mm and 350mm (BSI, 2000). These dimensions are proposed to reduce the risk of tripping. Given that on vehicle 3 boxes are being carried on the stairs, with the potential for poor line of sight, a wider going would be more advantageous to give a more secure footing. Additionally, each of the steps should be clearly defined by the use of adequate light and suitable colour contrast between the steps to further reduce the risk of tripping. The surface and 'nosings' (edge of the step) of the stairs should be slip resistant and a handrail support provided.

3.2.4 Receptacle / vehicle interface

Most of the receptacles examined in Section 3.1.2 had a rim around the top of the box that is used by crewmembers for hooking the box onto the side of the vehicle. The width of the receptacle rims (shown in Table 4) ranged from 15 mm to 35 mm, and the depth from 10 mm to 30 mm. The rims of the various boxes were not necessarily designed to function as hooks that can be used to attach them onto the vehicle. The rim, or flange, is a required element of the moulding and extraction manufacturing process of the kerbside collection boxes. As such, one manufacturer commented that the strength of the rim for supporting the box when loaded has not been tested.

The pictures in Figure 23 and Figure 24 show the methods of positioning the box on or against the vehicle when the contents are sorted. In Figure 23 the boxes have been placed on the vehicle lugs lengthways. However, the height of the lugs is much lower on one vehicle compared to the other. The design of the vehicle with the lower lugs is such that a greater degree of movement within the trunk is required due to the difference in height between the lugs and the entry flap into the stillage. The vehicle with the higher lugs has a loading hopper situated at the same height so there is little change in posture between bending to lift items out of the box and then throwing them into the hoppers.

Box placed on lugs lengthways at 1090 mm high

Box placed on lugs lengthways at 875 mm high

Figure 23 The positioning of the box on the vehicle when sorting the contents


Box placed on lugs widthways


Box supported for sorting using the body

Figure 24 The positioning of the box on the vehicle when sorting the contents

In Figure 24, one of the boxes pictured has been placed widthways on the lugs. This is likely to increase the strain on the box leading to damage occurring. The position of the box will also increase the horizontal reach distance of throwing items into the hopper, which would increase the strain on the lower back. The technique of supporting the box with the body is also illustrated in Figure 24. This technique results in static loading of the muscles and may potentially increase muscle fatigue as a consequence. A rim that is insufficiently wide enough to be easily situated on the lugs of the vehicle is likely to result in crewmembers opting to support the box with their body during sorting.

3.3 POSTURE AND TECHNIQUE FOR LIFTING AND CARRYING

3.3.1 Lifting receptacles

A variety of lifting techniques were employed to lift the 55 litre boxes, with the technique appearing to be dependent upon the box load or anticipated weight. The techniques used are illustrated in Figure 25 and Figure 26. The pictures in Figure 25 show the techniques used for lifting a 55 litre box with dedicated handles. In one technique the legs are kept relatively straight with the arm outstretched to reach the box handles. This appeared to be the more popular position adopted because it could be done with the least interruption to the walking pattern.

The second technique involved bending the legs and arms, bringing the lower back closer to the ground and the load. This technique was used for a particularly heavy box, with the position carefully adopted prior to the load being lifted. The results in section 3.1.6 indicate that the stooped posture increases lower back compression through lifting more than the squat posture.

Technique using the back to lift the box

Technique using the back and legs to lift the box

Figure 25 Observed techniques for lifting a 55 litre capacity box with dedicated handles

Figure 26 shows the hand position adopted when lifting a 4-position shell handle box and also a one handed lift. The 4-position shell handle box has a rim width of 35 mm and 30 mm depth, which enables the box to be grasped anywhere along the rim. In this case, to lift the box the crewmember has opted to grasp the rim at the corner of the box that locates his hands closer to his body. Although this method reduces the distance between the hand and lower back, it will increase the turning moment about the wrists.

The one handed lift seen in Figure 26 appeared to be used for boxes that contained less than those lifted two handed and they were therefore assumed to be lighter. This method enabled the crewmember to lift the box whilst still maintaining the walk. In this instance, grabbing the rim of the box, with the arm abducted, has resulted in the crewmember adopting a pinch grip therefore requiring the arm to counterbalance the forces as oppose to the shoulder or trunk. This technique also results in an asymmetric lift.

Lifting 4-position shell handle box

Lifting box with dedicated handles, using one hand only

Figure 26 Observed techniques for lifting 55 litre capacity boxes

The receptacle used for collecting food waste incorporates an attached handhold. The handhold also acts as a locking device for the container such that the handle has to be in the drop down position on one side of the bin in order to open the lid. Therefore, lifting techniques of the ‘bin’ type receptacle included picking the bin up by the handle with the lid closed or opening the lid and grabbing the top edge of the box with one hand and placing the other on the bottom of the bin to support the weight. These techniques are illustrated below in Figure 27.

Figure 27 Lifting of the food waste 'bin' from the kerbside using the handle and lifting the bin with the lid open grasping the top edge and bottom of the bin

3.3.2 Frequency of lifting

The frequency of lifting varies greatly because of the variations in household density and participation rates. Table 15 shows the estimated average number of lifts of the receptacle from the floor at the roadside. It does not take into account that each box could be lifted more than once, for example after lifting off the roadside, the box may be lifted again, above head height, to be emptied into a stillage or hopper.

The observed lifting frequency is taken from observation of the video footage and the calculated lifting frequency was taken from the average tonnage of waste collected over a known period of time, and divided by the average weight of the boxes. The calculated lift frequency gives an estimated average of the lifting frequency over the course of the working day. During periods of actual collection, frequencies can range up to about 2 lifts per minute. Averaged over a working day, frequencies appear to be in the region of 0.5 to 0.6 lifts per minute or one lift approximately every 1.6 – 2 minutes. According to L23 guidance (Health and Safety Executive, 2004) these are relatively infrequent operations. The results are set out in Table 15.

Table 15 The loaders' mean lifting frequencies

	Scheme 1	*Scheme 2*	*Scheme 3*
Observed mean lifting frequency	1.9 lifts per minute	1.35 lifts per minute	0.63 lifts per minute*
Calculated mean lifting frequency:	0.5 lifts per minute	0.53 lifts per minute*	0.63 lifts per minute*

*Note: These figures are a revision to those shown in the report issued in April 2006. The figures were amended in May 2006.

The lower calculated lifting frequencies for scheme 1 and 2 are likely to reflect that in practice there are several breaks in the lifting pattern throughout the day. It should be realised that one of the factors limiting frequency is the need to walk from one property to another or drive from one location to another so how this distance varies will affect the lifting frequency.

The highest number of lifts per minute, observed from the video footage, occurred in Recycling Scheme 1. This is likely as a result of the loaders not sorting the contents of the box, therefore enabling them to increase the rate of collection. However, this was not observed as being sustained for a significant period due to the participation rates. Increased participation rates will affect the balance of the round and lead to higher work rates and less rest between lifts unless the rounds are rebalanced.

3.3.3 Carrying receptacles

It was observed that the boxes were being carried mostly using two hands, directly in front of and against the body, at or slightly above or below elbow height. However, there are instances where the boxes were being carried using one hand, with the box held to the side of the body. It was not possible to determine the exact weights being carried using one hand but it appeared this technique was used for the lighter boxes.

Figure 28 shows crew members using two hands to carry the 55 litre box, of which one has dedicated handles and the other has a 4-position shell handle. Carrying the box using dedicated handles results in the centre of mass being displaced vertically downwards relative to the hands. The box is held horizontally straight in front of the body, with the handles held with power grips. These factors result in the hand and wrist posture remaining in a relatively neutral position.

In comparison, the 4-position shell handle box is being carried at the corner edge causing a turning moment about the wrist resulting in ulnar deviation and flexion. This is likely to increase the strain on the extensor carpi muscles of the forearm. This is just one technique of carrying the 4-position shell handle box and was not observed being carried like this by other crewmembers. However, this does illustrate the variation in technique that can occur, and which may influence the risk of injury.

Figure 28 Council workers carrying full recycling boxes using two hands, holding the container by the handles provided at or below elbow height

The carrying of the 'bin' receptacle tended to be done either using the handle, and carrying it to the side of the body, or holding it in front of the body, with one hand placed underneath the bin supporting the weight and the other placed on the top to provide support. These techniques are illustrated in Figure 29.

Carrying the 'bin' receptacle, using the handle, required the crewmember to flex the elbow in order to keep the bin off the floor and away from the body. Therefore the weight of the bin is taken through the arm and shoulder and the carrying posture illustrated requires that the elbow be maintained in flexion, thus requiring static activation of the elbow flexor muscles.

Figure 29 Carrying the 'bin' using one or two hands

Deviations from the main techniques observed included opening the lid of the bin receptacle whilst walking and carrying the 55 litre box using one hand (see Figure 30). Opening the bin lid whilst walking results in a number of changes in handholds as well as an increase in the potential of tripping due to reduced attention given to the surroundings. Carrying the 55 litre box in one hand and out to the side of the body would result in a less secure grip of the load, thus increasing the strain on the arm muscles and asymmetrical loading of the spine.

Figure 30 Opening a bin whilst walking and carrying a 55 litre box with one-hand

The carry distances observed on the collection round were generally less than 10 m, although it is estimated that carry distances over 10 m do occur when boxes are collected ahead of the collection vehicle, and from the opposite side of the road to the truck hoppers.

3.4 ENVIRONMENTAL FACTORS

3.4.1 Bin location

Generally residents are required to place the kerbside box at the edge of their property ready for collection. Of the recycling schemes observed, the houses were either terraced or part of an estate where the boxes were placed at the front of the property. Therefore, crewmembers were generally not required to manoeuvre in awkward spaces at the kerbside. However, it is likely that there are many situations where lifting and carrying of the kerbside box has to be done within a restricted space and this may influence the level of risk due to needing to use smaller muscle groups in the upper limbs to control the load in restricted space.

Coupled with the restriction on space, crewmembers will have to walk over a variety of surfaces, on uneven ground, with a restriction on visibility due to carrying the box. It is difficult to control for this factor and the use of a box adds to the risk because it is likely to reduce the line of visibility.

3.4.2 Influence of the weather

When performing manual handling in non-neutral thermal environments, i.e. hot or cold environments, individuals will have varying physiological responses. Thus, for some individuals manual handling in non-neutral thermal environments will increase the physiological strain. Working at low temperatures may also impair dexterity. However, if suitable clothing is worn, and when working in hot environments there is regular access to drinking water, there is minimal effect of the environment on performing the task of lifting and carrying kerbside collection boxes (Powell *et al.*, 2005).

3.4.3 Co-operation of the residents

The collection of recyclables requires a greater degree of cooperation by residents than the previous ‘black-bin’ style refuse collection where all waste was placed into one bag. Residents now have to sort through their waste, placing it into the correct container or bag ready for collection. Therefore, residents are required to follow instructions issued by the local authorities on what waste is to be collected and how it is to be separated. Residents not following instructions add to the difficulties of recycling collections. Examples from the recycling schemes studied include:

1. Not washing out tins or glass jars, resulting in the presence of maggots during the summer months.

2. Not placing food waste into plastic bags resulting in the contents sticking to the side of the bin and the crewmembers having to shake the bin to empty it.

3. Not separating recyclables using plastic bags resulting in increased time taken to sort the contents.

A further factor to consider is the regularity with which the boxes are placed at the kerbside i.e. the possibility that residents will accumulate waste until the box is full before leaving it out for collection.

3.5 WORK ORGANISATION

3.5.1 ‘Job and finish’

‘Job and finish’ is the term used to describe the work method whereby the crews may finish work once the collection round for that day is completed. In all three recycling schemes studied, ‘job and finish’ work organisation methods were used. This method of work may encourage crewmembers to work at a fast pace to ensure completion of the work as quickly as possible. Therefore, this work method has the potential to discourage crew members from working at a reasonable pace and/or taking rest breaks.

The observation of the recycling schemes showed that the opportunity to rest is influenced by the participation of residents, the type of houses being collected from, and the requirement to move to a different collection point or off-load the vehicle mid-way into the shift. In circumstances where there are opportunities to rest as part of the normal pattern of work, and the individuals can control and pace the work, the work method of ‘job and finish’ is unlikely to impact upon the overall risk of musculoskeletal injury.

3.5.2 Supervisory effectiveness

Good supervision can form a powerful part of the overall management of the MSD risks within an organisation. Supervisors or team leaders influence the health and safety standards that are acceptable to the crewmembers. This means that if the supervisor tolerates low standards, the crewmembers are likely to tolerate low standards and regard these standards as acceptable (Health and Safety Executive, 2000). Therefore supervisors are in the unique position to influence how well an organisation meets health and safety requirements (Health and Safety Executive, 1997).

4 DISCUSSION

4.1 ACCEPTABLE LIFTING WEIGHT

Mital *et al.*, (1997) developed guidelines for the maximum acceptable weights and forces for lifting, lowering, pushing, pulling and carrying tasks, based on psychophysical data. The guideline weight for lifting is obtained from tables using the variables of box width, vertical distance of the lift, position of the box at the origin and destination of the lift, and the frequency of lifting. The guidelines are separated into the percentage of the industrial population who can lift the maximum weight in line with the aforementioned variables.

Utilising the guideline tables, the proposed acceptable lifting weight for 90% of the industrial population of males, given a box width of 395 mm, a vertical lift distance of 76 cm (based on lifting up to elbow height), lifting in the floor level to 132cm height region at a frequency of twice a minute (taken as a maximum lift frequency in line with observations), is 13 kg. For females this weight is 7.5 kg.

In terms of the weights observed on the recycling schemes, 75% of the boxes were above 7.5 kg and 26% were above 13 kg. The highest number of boxes that were above the acceptable weight limits was observed in recycling scheme 3. Using Snook's revised tables (Liberty Mutual, 2004), the average box weight of 11.38 kg seen on recycling scheme 3 means the task of lifting kerbside boxes is acceptable to 20% of the BFA population based on 2 lifts a minute, a 250 mm hand distance and a 760 mm lifting distance when lifting a box above knuckle height but below shoulder height. The average box weight of 11.38 kg is acceptable to more than 90% of the BMA population. A box weight of 20 kg is acceptable to only 50% of the BMA population. This percentage is based on two lifts a minute of 20 kg over an 8 hr day, which is unlikely to occur given the results of the observation. The tables indicate that boxes which weigh over 13 kg will be unacceptable to more than 10% of the BMA population and so in order to reduce the risk of injury, where possible, box weights should not exceed 13 kg. Furthermore, these figures indicate that the task of lifting kerbside boxes is generally unacceptable to all but a few females.

The highest percentage of unacceptable box weights was observed in Recycling Scheme 3, the mixed recyclables collected bi-weekly. The lowest percentage of unacceptable box weights was observed in the weekly mixed recyclables collection. This suggests that a weekly collection would assist in reducing the weights of the boxes to be collected. The evidence is that when the frequency of lifting is increased, the acceptable weight decreases (Pinder, 1997). However, because frequency of lifting on a recycling collection round depends largely on the distance between participating properties, the frequency of lifting is unlikely to increase when collections are weekly rather than bi-weekly, so the net effect would be to keep the frequency of lifting approximately constant while decreasing the weight of individual boxes. This would have wider implications for the number of crews required to operate a recycling scheme and hence would affect the costs.

4.2 ACCEPTABLE WEIGHT FOR CARRY DISTANCE

From the guideline tables (Mital *et al.*, 1997), the proposed acceptable carrying weight for 90% of the industrial population of males, using a carrying height of 111cm (the mean elbow height for adult males) at a frequency of once a minute and an 8.5 m carrying distance is 13 kg. For females, the tables assume the carrying height is 105 cm (mean elbow height for adult females), which gives an acceptable carrying weight of 12 kg. Therefore, just over one quarter of the weights observed are outside the guidelines for the working population.

Given the acceptable lifting weights outlined in section 4.1, it would be appropriate to conclude that to accommodate 90% of females, box weights need to be controlled such that the average weight does not exceed 7.5 kg. It is likely that informal self-selection will result in weaker members of the population not taking work as waste/recycling collectors or not remaining in the job. Traditionally, waste/recycling collection has been a male-dominated job. The combination of the perception of it as heavy work, and male-female differences in strength are likely to have contributed to this. It is likely that with expansion in the waste and recycling industry, and changes in employment patterns that the numbers of females working as waste/recycling refuse collectors will increase.

Working within these guideline weights is not, on its own, a suitable and sufficient risk control because the weight of the load is dependent upon a variety of other factors such as vertical lift distance and frequency. Therefore, careful assessment of the range of factors is required to ensure risk controls are suitable and sufficient.

4.3 EFFECT OF USING A LID

The calculation of maximum box weights was performed under two conditions 1) filling the box to the top edge whilst still being able to fit a lid, and 2) filling the box above the top edge. The maximum weight difference observed between these conditions for the same type of box and material was 4.8 kg. The highest weight observed using a lid with the box loaded with glass and newspapers was 17.4 kg and without the lid this was 22.1 kg. Therefore, it can be concluded that the use of a lid is an effective control in reducing the weight of the load. If a box were stored outside, a lid would also prevent rain from entering the box. Even though boxes typically have drain holes, the addition of water to absorbent material such as newsprint would increase the overall weight of the contents.

Potential issues associated with the use of the lid include:

1. Residents not using or losing the lids;

2. The impact upon the crew members in terms of having to remove the lids to sort or empty the box;

3. Loose lids being blown around on windy days after collection.

In order to incorporate the use of a lid as a method of load control, these issues would need to be addressed, which does give the potential for solutions to be proposed by manufacturers.

4.4 LIFTING AND CARRYING TECHNIQUE

Both one handed and two-handed lifting were observed. Two-handed lifting using suitable handholds encourages the load to be lifted symmetrically, distributing the load evenly either side of the body (assuming the weight is evenly distributed within the container). However, a two handed lift was observed where the hands were placed at the edge of the box, close to the body, away from the centre of gravity of the load and placing more stress on the wrists and shoulders. This is not recommended and should be avoided where possible.

One-handed lifting results in the load being taken on one side of the body, thus loading the body asymmetrically. This results in the forces required to lift being placed on weaker structures within the body due to the one sided lift. Therefore when undertaking frequent lifting tasks, two-handed lifting is preferred to one-handed lifting.

The same principles also apply for carrying the boxes. The risk of injury will be increased where a container is carried asymmetrically. In instances where the load has to be held up off the floor and carried asymmetrically (see Figure 23) the muscles of the arm will fatigue more quickly. Therefore containers that require this action should be avoided.

When carrying two-handed containers, a crewmember was observed holding the box at the corner edge with the hands close to the body. This technique transfers a greater percentage of the load onto the wrists increasing the risk of injury. However, it is possible this technique was used as an alternative to holding the box further away from the body to avoid it interfering with the walking action

To increase the awareness of the potential impact of handling techniques, suitable training should be provided. Effective training should complement a safe system of work and not be relied upon as the single source of manual handling risk control (Health and Safety Executive, 2004). Training will equip workers with a greater knowledge and awareness of the task but will not guarantee safe practice.

4.5 INFLUENCE OF BOX STYLE RECEPTACLE DIMENSIONS

Comparing the box dimensions with recommended tray dimensions (Chengalur *et al.*, 2004) shows the box width and tray length of nearly all the boxes examined to exceed the recommended dimensions of 360 mm and 480 mm respectively but not the upper limit. In all cases the depth of the boxes exceeded the recommended dimension of 130mm. However, NIOSH propose (Waters *et al.,* 1994) that an optimal container design has a frontal length that is ≤400 mm and a depth that is ≤300 mm with no specification given to the width. The box dimensions influence the body in the following ways:

1. A greater tray length dimension will increase the number of people who would have to abduct their arms in order to lift the box. Abduction of the arms results in the load being placed on the hand, wrist, and shoulders instead of the arms and back.

2. A greater depth dimension will increase the number of people for whom carrying the box is likely to interfere with walking, thus increasing the potential for the box to be held higher and/or away from the body. However, reducing the depth of the box will conversely increase the vertical lift distance so an appropriate balance is required.

3. The greater the width dimension the further away the centre of mass of the load is from the handler’s lumbar spine, resulting in increased stress on the spine.

The results of the lower back compression for box types 1 to 7 show that there is at most a 5% difference between the lowest and highest compression forces when lifting the box in a stooped or squat posture. This suggests that for both lifting techniques and for the boxes examined, there was little effect on lower back compression from changes in the dimensions of the boxes.

Using the NIOSH depth limit (Waters *et al.,* 1994) it would seem reasonable to propose that the most viable box options at present are those that fall below this limit, given that on the width and length dimensions the boxes fall within the upper limits proposed by Chengalur et al. (2004). It would appear that the depth of the box is not greatly influencing the lower back compression so therefore to opt for the lower boxes would reduce the likelihood of the box interfering with walking.

4.6 INFLUENCE OF THE HANDHOLDS

An effective handle is critical to the handling of the load and can help reduce the risk of injury by encouraging a better handling technique and enabling the use of a power grip, which maximises the use of the muscles. A power grip provides a good gripping force for lifting heavy containers where accurate control of the container is not needed (Drury, 1985). Chengalur *et al*., (2004) recommend dimensions for satisfactory styles of handhold for carrying a tray. This includes a handhold cutout, gripping block, contoured gripping block, and drawer pull. Recommended dimensions are also given for one-handed handles.

Some of the boxes assessed had a satisfactory handhold including a drawer pull and cutout style handhold. Two more types of box, and the 'bin' style receptacle were classified as having a one-handed style handhold. It was found that none of the satisfactory or one-handed handholds met all of the recommended dimensions (Chengalur *et al.*, 2004), which may reduce the effectiveness of the handle.

One of the box types classed as having a one-handed style handhold actually had handles located on either side of the box thus enabling both hands to be used. The other one-handed handhold box, designed to be picked up using one hand, results in asymmetric lifting. Asymmetric lifting increases the shear forces acting within the spine and should be avoided where possible. The unsuitable handholds were those that formed part of the rim, creating an overhang style handhold, which tend to cause high pressure on the fingertips. The handles on the 'bin' style receptacle did meet all the requirements for a one-handed handle.

4.7 VEHICLE DESIGN AND RISK ASSOCIATED WITH POSTURE

All three vehicle designs at some point required the load to be lifted above shoulder height in order to empty or sort the contents into the vehicle. In some more than 99% of the British adult population would have to lift or sort above shoulder height. Manoeuvring around vehicle 2 and 3, the stillage loaded vehicles, also placed restrictions on movement thus resulting in cases where the crewmembers had to twist whilst lifting the load above shoulder height. Twisting the trunk and lifting a load at the same time significantly increases the stress placed on the lower back. Lifting above shoulder height places additional stresses on the arms and back (Health and Safety Executive, 2004).

The increased risks associated with lifting above shoulder height and twisting the trunk is reflected in the calculated REBA scores where 6 of the 14 postures assessed were classified as high, which suggests that action is necessary soon.

4.8 RECEPTACLE / VEHICLE INTERFACE

Where sorting of the contents of the kerbside containers is required, crewmembers were observed placing the box on the lugs of the vehicle. However, there were cases where crewmembers used a part of their body to support the box against the vehicle, which is likely to result in static loading of the muscles resulting in fatigue. Furthermore, the crewmember is more unbalanced during loading. Therefore, it is desirable that the boxes are placed on the lugs of the vehicles. It is important that the rim of the box is sufficiently wide and strong enough for it to be located onto the vehicle, thereby making it easier for this work method to be used.

4.9 FUTURE RECEPTACLE DESIGN

To enable local authorities to maximise recycling rates whilst reducing the risks of manual handling injuries, manufacturers of receptacles are creating innovative solutions that can be used within existing schemes. One such example is a product called the ‘recycle station’ and is shown below in Figure 31.

The recycling station reduces the risk of manual handling injury and tripping whilst carrying the box. However, there is still the requirement to lift the various containers out of the wheelie bin, which results in an increased frequency of lifting coupled with a greater degree of control required to remove and re-locate the boxes within the bin. The box contents can also be separated using dividers, and whilst this may make it easier to sort the contents, it may result in an uneven load. Furthermore, it is not known if this design will reduce the risk of injury given that lifting is combined with pushing and pulling both the wheelie bin and boxes.

Figure 31 A potential design solution aimed at reducing the risk of manual handling injuries

5 MAIN FINDINGS

1. The maximum kerbside collection box weights observed in the laboratory were higher for mixed glass and newspaper than for glass only. The highest maximum box weight observed in the laboratory for mixed glass and newspaper was 22.1kg.

2. The use of a lid reduced the kerbside collection box weights observed in the laboratory for both glass only and mixed glass and newspaper.

3. Kerbside collection box weights appear to be lower where recyclables are collected weekly when compared to bi-weekly collections.

4. The length and width dimensions of kerbside collection boxes do not exceed proposed upper limits of an optimal container design. However, container depth does exceed the recommended upper limit.

5. The handle design of the boxes could be improved to meet the recommended type and dimensions. In particular the handholds should be designed to account for the use of protective gloves.

6. There is little difference in terms of injury risk when lifting kerbside collection boxes of varying dimensions, including lifting those of reduced depth.

7. The National Institute of Occupational Safety and Health (NIOSH) recommend a maximum compressive force of 3.4kN on the L5/S1 intervertebral disc. It is believed there is an increase in risk of low back injury where the limit of 3.4kN is exceeded. All of the kerbside collection boxes assessed reached the limit of 3.4kN, for males, at a weight of 13kg when lifting in a stooped posture.

8. The revised Manual Materials Handling Guidelines (Liberty Mutual, 2004) suggest that more than 90% of the British male and 20% of the British female adult population would find it acceptable to lift an 11.38 kg box (an average observed from the recycling schemes studied) twice a minute for a period of 8hours.

9. When loading recyclables into either the hoppers or stillages of the collection vehicle, lifting above shoulder height was observed. This is known to increase the risk of injury. The results of a Rapid Entire Body Assessment (REBA) indicate that lifting above shoulder height created a ‘high’ risk posture and action is necessary ‘soon’.

10. When loading recyclables on-board the vehicle, lifting above shoulder height and twisting were observed due to restriction on movement caused by space constraints. In some cases more than 99% of the British male and female adult population would have to reach above shoulder height to put recyclables into the stillages.

11. When tipping the contents of the recycling box into a hopper, a two-handed tipping technique is a more suitable posture than a one-handed technique.

12. If access onto the vehicle is required when carrying a box, the stair design should be optimised to support this operation and reduce the risk of slips and trips.

13. The lugs situated on the side of the vehicle were generally used for supporting the box during sorting. However, not all crew members used the lugs, preferring instead to support the box with their body.

14. Generally, boxes were lifted using a two-handed technique in a stooped posture. The stooped posture results in slightly higher lower back compression when compared to a semi-squat posture.

15. Where a box is lifted or carried by grasping the edge of the box at a point closest to the body, an increased strain is placed on the wrists and forearms.

16. The observed and calculated lifting frequencies indicated that loaders are performing on average 1 or 2 lifts every minute.

17. There were occasions where the carry distance was greater than 10m but this is dependent upon the collection area and participation rates.

18. Carrying the box will restrict visibility and is likely to increase the risk of tripping and slipping due to the range of floor surfaces that crew members have to negotiate.

19. The evidence suggests that if suitable clothing is worn and there is regular access to drinking water there is minimal non-neutral thermal environmental effect on performing the task of lifting and carrying kerbside collection boxes.

6 RECOMMENDATIONS

1. Previous research suggests that the use of wheelie bins reduces the risk of manual handling injury compared to handling non-wheeled containers. Therefore, where possible it would be more appropriate to use wheeled bins for the collection of recyclables.

2. Where boxes are used, reduce the capacity of the boxes to at most 40 litres to provide a method of weight control. The maximum weight observed for a 40 litre box containing mixed glass and newspaper, including a lid, was 12.8 kg. This figure is below the level likely to exceed the NIOSH 3.4kN biomechanical criterion. Also, this weight is acceptable to at least 90% of the British male adult population.

3. The use of a lid would appear to be a practicable method of load control of the box reducing the occurrence of overfilling, and protecting the box contents from rainwater. However, there may be consequences for crew members in terms of removing the lid at collection. A more suitable lid, or alteration in the instructions given to residents may therefore be required.

4. The type of recyclable material collected at the roadside in the kerbside box will affect the weight potential of the box, and consideration needs to be given to this factor by the local authority in terms of their waste management system as a whole.

5. In order to reduce injury risks, crew members should use both handles of the boxes, i.e., they should engage in two-handed lifting, carrying and tipping.

6. Boxes with handholds separate from the rim are preferred as this encourages crew members to pick the box up using the handholds. To optimise the handholds the handhold dimensions should be in line with existing ergonomic recommendations.

7. Manufacturers should ensure that the rim of the box is wide enough and sturdy enough to allow it to be readily located onto the lugs of the vehicle rave rail.

8. The evidence suggests that weekly collections will result in lower weight lifts and a lower risk of injury for that particular lift. However, consideration should be given to the impact of the increased frequency of collection and exposure to a range of hazards. The impact of these risk factors is currently being researched by HSL with the outcome of the work being available in November 2006.

9. Local authorities and their contractors should provide instructions to residents on handling technique and the requirement to not overfill the boxes, and to leave the box for collection on a regular basis, even if the box is not full.

10. Crew members should avoid carrying boxes further than about 10m without resting. Irrespective of the distance carried, where boxes weigh approximately 13kg or more (see recommendation 2) crew members should divide the contents of the box and/or seek assistance from a work colleague before attempting to lift and carry the box to the vehicle.

11. Crew members should be given task specific training that is supported and encouraged by managers.

12. The vehicle design should take account of anthropometric measurements and aim to accommodate a high proportion of the population. Ideally, vehicles should be designed so that workers do not have to reach above shoulder height to empty or sort the contents of the kerbside box.

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