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Human Factors: The Journal of the Human Factors and Ergonomics Society 1986 28: 295

DOI: 10.1177/001872088602800305

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An Evaluation of Knife Handle Guarding

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This research evaluated two variables affecting the performance of tang guards in preventing injury due to the hand slipping forward on a knife handle: the radius of transition from the handle to the blocking portion of the tang and the height of the tang. For the radii evaluated, there was no effect for either men or women. The guard height, however, did have a significant effect for both genders. There is a height, different for men and women, that appears to be critical. Guard heights exceeding this critical height do not enhance the capability of the guard to prevent the hand from slipping. Guard heights less than this critical value are less capable of preventing slipping.

INTRODUCTION

Present-day meat packing has evolved from small butchering operations to a large industry using modern work methods. In this evolution many things have changed, but the basic tool, the knife, remains relatively unchanged. The knife is involved in many lost-time accidents and permanent disability cases (Aghazadeh and Mital, 1985). A problem in knife design is the configuration of the handle (Armstrong, Foulke, Goldstein, and Joseph, 1981; Riley and Cochran, 1980).

As workers in the meat-packing industry perform their assigned cutting tasks over an eight-hour day, fatigue sets in. This is especially true of the muscles involved in maintaining a grasp of the knife handle, as these muscles are statically loaded. Static loading of muscles inhibits the blood flow necessary to bring replacement energy supplies and remove waste products critical to muscle metabolism. This causes accelerated fatigue in

the muscles involved. To accentuate this problem, a knife handle may become slippery due to body fluids of the slaughtered animals. This requires a tighter grip, which causes even more static loading of the muscles.

In attempting to stab the knife into the meat, the worker occasionally hits a bone or a work surface with the knife blade, resulting in abruptly stopped penetration. If the hand slips in this situation, it slides over the blade, with the possibility of severe injury and often permanent disability.

Present knife-handle designs do little to prevent this sliding over the blade. Some provide an indentation or small tang to stop the first finger from going forward. This is inadequate when the knife is slippery and/or the worker is fatigued. Also, the surface texture of wooden or plastic handles does little to inhibit the slipperiness caused by animal body fluids.

Guards

The function of a guard is to prevent the hand holding the knife from slipping forward

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onto the cutting edge. The guard also offers some protection when the hand contacts a sharp projection such as a bone.

There are four basic methods of preventing the hand holding the knife from slipping over the cutting edge. Three of these place a barrier or enlargement between the hand and the cutting edge. The fourth attaches or ties part of the hand to the rear (away from the blade) of the handle. In this fourth method, generally the little finger is placed in a loop made of nylon or other durable material, which is attached to a swivel on the rear end of the handle. With the little finger in the loop, the hand cannot slip over the cutting edge. Although this method does keep the hand from sliding over the front of the handle and onto the edge, it has some drawbacks. First, the knife can be used in only a limited number of positions without removing the little finger from the loop. Second, the loop tends to irritate the little finger, causing blisters and calluses, and may even lead to functional problems of that finger.

The first of the barrier-type guards in use is the simple tang. This is a protrusion (usually an integral part of the wooden or plastic handle) downward from the handle, as in Figure 1. This is the most common type of guard and is present to some extent on every knife used in quantity by meat packers. The second barrier-type guard adds a side plate to the handle already having a tang guard. Generally this protrudes about 0.6 to 1 cm at a right angle from one side of the handle. The third barrier-type guard is sometimes called the bail guard and consists of a heavy wire loop placed on the handle, as can be seen in Figure 2.

The tang guard is the most prevalent. The side plate guard can be effective, but it may irritate the worker's hand, and anything that protrudes from the side of the handle can interfere with cutting close to the bone or

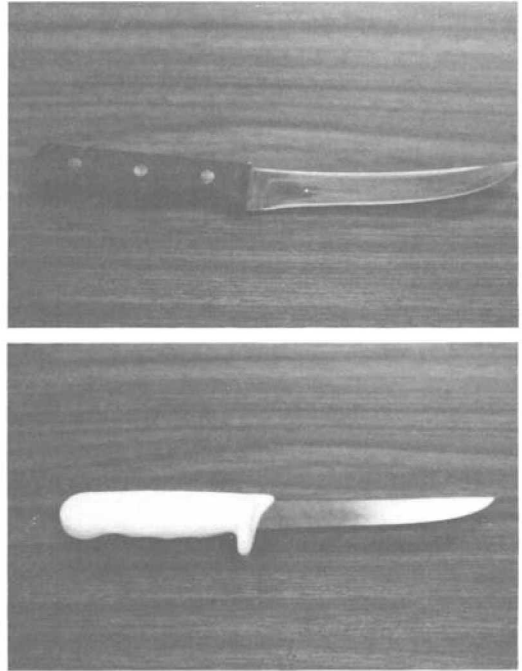


Figure 1. *Handles with tang barrier type guards.*

hide in some operations. The bail guard is clumsy and interferes with some cutting operations and rapid changing of knife positions in the hand.

Because of the potential of work interference, it is believed that the type of guard most likely to be accepted and used will be a tang guard. Since virtually all knives have

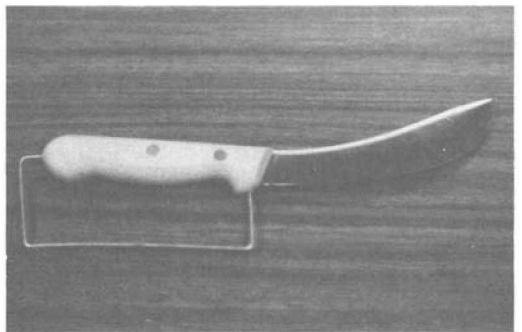


Figure 2. *Handle with bail barrier type guard.*

tang guards and there are still injuries from the hand slipping over the cutting edge, it must be concluded that at least some of the tang guards on knives currently in use are inadequate.

Knives used in meat packing come primarily from the Chicago Cutlery Company and Dexter Russell, Inc. Chicago Cutlery manufactures many kinds of wooden-handled knives, all of which use the same basic shape and handle size with minor differences in the dimensions. The basic shape and dimensions for three of the Chicago Cutlery wooden handles are in Figure 3 and Table 1. Chicago Cutlery has a plastic-handled knife called the BioCurve®. The shape and dimensions of this handle are also depicted in Figure 3 and Table 1. Dexter Russell has many wooden and plastic handle designs. The dimensions of two of these handles are also given in Table 1.

The tang, indentation, or guard, which should aid in keeping the hand from sliding forward over the cutting edge, appears to be inadequate for the Chicago Cutlery wooden handles, marginal for the Dexter Russell wooden handle, and probably adequate for the Dexter Russell plastic handle and the Chicago Cutlery plastic handle. This is evidenced by the height of the tang, dimension *h*, which is the difference between dimensions *a* and *g* (Table 1). Also of possible im-

portance is the radius of curvature (Table 1) of the transition from the handle to the tang or guard. On all but the Dexter Russell wooden handle and the Chicago Cutlery plastic handle this radius is small, which tends to make the guard more effective. On the Dexter Russell wooden handle and the Chicago Cutlery plastic handle, this radius is much larger, which might tend to function as a ramp and facilitate the finger slipping over the tang.

OBJECTIVE

The two most important parameters of tang guards evaluated in this research were the effective height of the tang and the radius of curvature of the transition from handle to tang. Effective height is the vertical height of the guard above the handle. This is measured from the low point of the area on the handle where the index finger will be placed when the knife is held in a slicing position, to the highest point of the tang before it begins to curve toward the blade. This height does not include that part of the tang guard that begins to curve or recurve toward the blade.

METHOD

Experimental Design

The experimental design had three factors, with blocking on subjects. The factors were

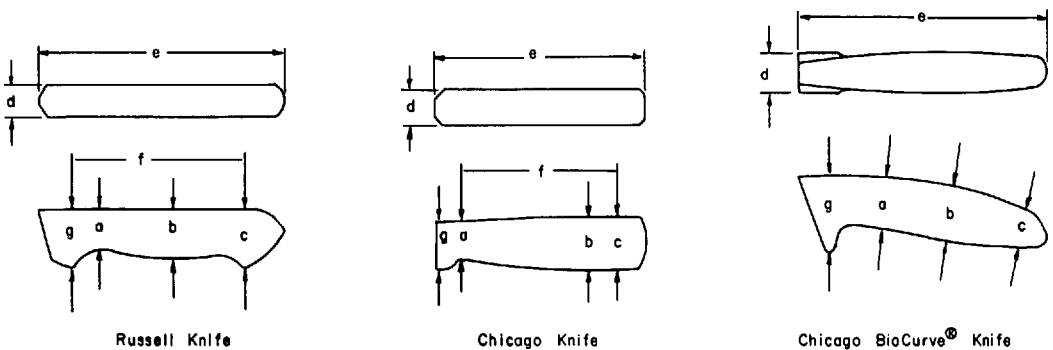


Figure 3. Places of measurement of dimensions of knife handles.

TABLE 1

Dimensions of Knife Handles*

Knife	Dimensions (cm)								
	a	b	c	d	e	f	g	h (g-a)	r
Russell Plastic Handle	2.77	3.28	3.15	2.24	13.34	8.26	4.45	1.68	0.53
Russell Wood Handle	2.29	3.00	2.62	1.87	13.34	8.26	3.18	0.89	0.95
Chicago 94-5	1.83	2.84	2.54	2.16	11.43	9.86	2.24	0.41	0.56
Chicago 96-6	2.01	2.90	2.62	2.16	11.43	9.86	2.24	0.23	0.61
Chicago 72-2	2.08	2.84	3.00	2.16	11.76	10.03	2.54	0.46	0.60
Chicago BioCurve®	2.79	2.97	2.16	2.22	13.65	—	4.32	1.53	0.95

* Note: See Figure 3 for a description of the measurements.

the gender of the subject, the guard height, and the radius of curvature of the transition from the handle to the guard. Subjects were nested under gender. Three replicates of the experimental data were collected.

Variables Tested

The four guard heights tested were 0.508, 1.016, 1.524, and 2.032 cm. Guard height is dimension h of Table 1. The three radii of curvature were 0.533, 0.800, and 1.067 cm. All combinations of the four heights and the three radii of curvature were tested.

The range of the three radii of transition tested more than covered those found on present meat-packing knives. The smallest, 0.533 cm, was approximately the same as the smallest found on the meat-packing knives measured. The largest radius was larger than any found in measuring meat-packing knives. The height dimensions were based upon a small sample estimate (5 subjects) of the height of the second phalange of the forefinger for males. This yielded a diameter estimate that was approximately 2.032 cm. Male subjects were used because it was believed that if a guard was adequate for the larger male finger, it would be even better for the smaller female finger. The guard heights used were 25, 50, 75, and 100% of the fore-

finger diameter estimate. The smallest guard height tested is greater than the dimension h of the wooden handles on the Chicago Cutlery knives of Table 1. The largest height is greater than the dimension h of any handle of Table 1. The radii used were selected to span the range on present handles in Table 1.

Subjects

Each guard was tested on nine male and nine female subjects. A concentrated effort was made to recruit subjects with meat-cutting experience, which resulted in approximately half of the subjects being either currently employed or former meat cutters. The remainder of the subjects were machinists, secretaries, technicians, homemakers, laborers, teachers, and students.

Slippery Film Method

The testing for this study was conducted under slippery film conditions. That is, a slippery film was applied to the handle and guard prior to its being grasped by the subject for a trial. The purpose of this was to eliminate the effect of the surface finish of the handle, to more closely simulate actual meat-packing conditions, and to get a more accurate assessment of the inherent characteristics of each guard. It was believed that

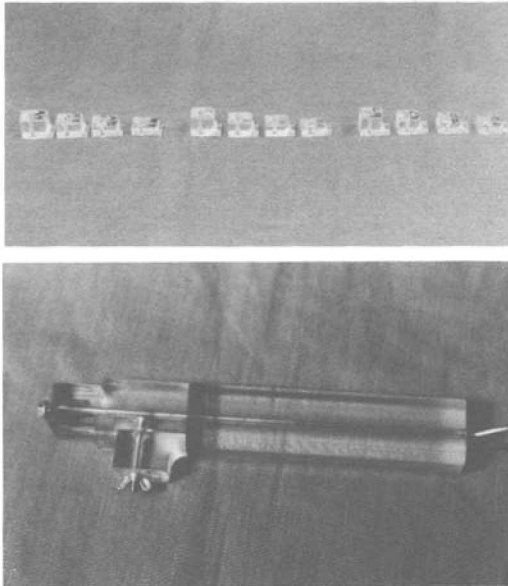


Figure 4. Guards tested and the handle with one of the guards mounted for testing.

covered with the slippery liquid, was worn. This also prevented the liquid from being absorbed by the hand and made for an easy clean-up. STP®, an engine oil additive, was selected as the slippery film. It was effective in reducing the friction between the plastic glove and the plastic handle.

Apparatus and Testing

A rectangular handle with a width-to-height ratio of 1:1.75 was used for the testing. This handle was 11 cm in perimeter and had rounded corners. The various guards were attached to this handle (see Figure 4). The test consisted of having each subject put on a plastic glove, grasp the slippery handle with a guard on it, and push in the direction of the guard as hard as possible. The rear of the handle was attached to a cable tensiometer (Pacific Scientific Co. Model T5) with a peak force indicator. The subjects pushed against the guard. The maximum force was reached when subjects slipped over the guard or could not push any harder.

The reasoning behind this test was that a guard that allowed the subject to exert more pushing force would also be more likely to

the slippery film would accentuate any advantages or disadvantages of a guard, and that this would make the tests more sensitive to real differences. To ensure that the coefficient of friction was constant from trial to trial, a disposable plastic glove, which was

TABLE 2

Analysis of Variance of the Maximum Force with Guards for All Subjects

Source	Error Term	Sum of Squares	D.F.	Mean Square	F
G—Gender	P(G)	551531.04	1	551531.04	27.38*
H—Height	HP(G)	172891.62	3	57631.00	65.26*
R—Radius	RP(G)	1694.50	2	847.25	2.96
P—Subjects(G)	Error	322254.17	16	20141.00	366.17*
GH	HP(G)	54295.65	3	18099.00	20.50*
GR	RP(G)	1422.98	2	711.49	2.49
HR	HRP(G)	787.75	6	131.29	0.50
HP(G)	Error	42386.89	48	883.06	16.05*
PR(G)	Error	9156.15	32	286.13	5.20*
GRH	RHP(G)	937.05	6	156.18	0.59
PRH(G)	RHP(G)	25242.38	96	262.94	4.78*
Error	RHP(G)	23761.71	432	55.00	

* Significant at $\alpha = 0.05$

prevent the hand from sliding over it and onto the blade.

RESULTS

Table 2 shows the results of the analysis of variance on the maximum push force with guards on the handle. The radii of transition were found not to affect significantly the maximum force exerted. The height of the guards did affect the maximum force exerted.

Because the interaction of gender and guard height was significant, the two factors cannot be considered separately. The mean forces of the four heights are shown graphically in Figure 5 for males, females, and all subjects. In examining these mean forces for each of the guard heights for male subjects using the Tukey's test (Table 3), the forces as-

TABLE 3

Results of the Tukey's Test of Guard Height for Male Subjects

Guard Height (cm)	0.508	1.016	1.524	2.032
Mean (Newtons)	112.67	152.72	171.35	178.22

sociated with the shortest guard (0.508 cm) were significantly less than the other heights. The forces associated with the next shortest guard (1.016 cm) were significantly less than for the two higher guards. The two highest guards (1.524 and 2.032 cm) did not have significantly different forces from each other in maximum force exerted by male subjects.

For female subjects, the forces exerted when using the lowest guards (Figure 5 and Table 4) were significantly less than for the other three. The three highest guards were not significantly different from each other.

The Tukey's test for differences between the guard height for all subjects (Figure 5) is the same as that for the male subjects. The highest two guards were not different from each other but were different from the lowest two guards (which were different from each other).

CONCLUSIONS

There are several conclusions that can be made from the results of the analyses of the guard evaluation data. First, the radius of

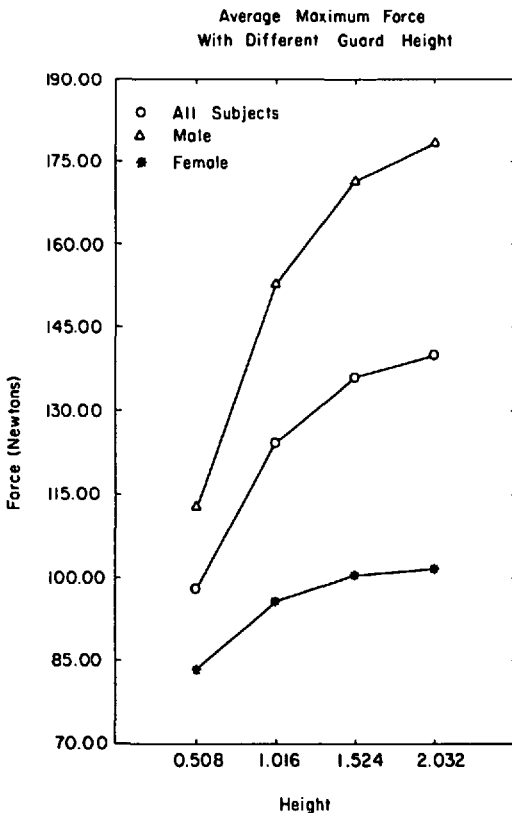


Figure 5. Average maximum force with different guard heights.

TABLE 4

Results of the Tukey's Test of Guard Height for Female Subjects

Guard Height (cm)	0.508	1.016	1.524	2.032
Mean (Newtons)	83.50	95.87	100.50	101.70

transition (in the range of radii tested) had no effect on the maximum force exerted. Therefore, the radius of transition (in the range of radii tested) did not function as a ramp to facilitate the finger slipping over the tang. Second, for female subjects there was minimal improvement in the force exerted when the guard height was more than 1.016 cm. Third, there was minimal improvement in the force exerted by male subjects when the guard height was more than 1.524 cm. If tang guards were made high enough for male subjects to maximize push, they would be more than adequate for female subjects. Therefore, a guard height adequate for male subjects will also be adequate for female subjects.

In general, guard heights of 1.016 cm or less may be inadequate (depending on gender), and guard heights of 1.524 cm or more should be adequate for all workers. Inherent in these conclusions is the assumption that under the conditions of a slippery handle, the minimum guard height at which maximum force can be exerted is also the minimum height at which a tang guard becomes effective in preventing the hand from sliding off the handle.

The fact that this testing has determined

that a 1.016-cm-high guard may be inadequate should be related to the heights of present meat-packing knives featured in Figure 3 and Table 1. Two of these have a total guard height higher than the effective height of 1.016 cm. These are the plastic-handled Dexter Russell knives and the new Bio-Curve® knives from Chicago Cutlery; at this time, however, these are not the most commonly used knives in meat packing. It would thus appear that tang guards for most knives presently used in meat packing are inadequate.

ACKNOWLEDGMENT

This project was supported by Grant No. 1R01 OH 01134-01, awarded by the National Institute for Occupational Safety and Health.

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