How Do Different Meat Temperatures Affect Knife Force?

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Abstract: Meat cutters have long since claimed that knife forces increase with lower meat temperatures. This study was performed to find out what effects the meat temperature has on cutting forces. In addition, the same issue was addressed for pure fat. One hundred and forty four samples of lean meat and of fat respectively were collected and put overnight in one of three refrigerators with temperatures 2, 7 and 12°C, 48 in each. These samples were cut while measuring cutting forces in an Anago KST Sharpness Analyzer machine. The results show that there were no significant differences in knife forces concerning lean meat at the three temperatures. However, the force in pure fat at 2°C was significantly increased by 30% compared to the other temperatures. The forces in fat were generally three times higher than for lean meat, regardless of temperature.

Keywords: Deboner, fat, meat cutting work, MSD, pork, repetitive work, temperature.

1. INTRODUCTION

Industrial meat cutters are a group with high risks for musculoskeletal disorders such as carpal tunnel syndrome [1, 2], epicondylitis [3] and several other upper extremity disorders [1, 4-6]. This is natural consequence of the character of work, being physically demanding [7] and highly repetitive [8] and performed with high velocity [9]. High hand forces are exerted during meat cutting [10]. Forearm loads have been estimated by surface electromyography to be 8% of maximum voluntary contraction (MVC) statically, with a median level of 20% MVC and peak loads up to 60% MVC [11]. Normally, the meat cutters hold a knife in their hand during large part of a work shift (up to 98% of total time) [12]. The risk situation is also aggravated by frequent extreme wrist postures [2]. Carcasses are refrigerated due to hygienic demands before deboning. Depending on local production procedures meat temperature can vary. The Swedish regulations, which also are valid within the European Union, state that while cutting meat, room temperature shall be no greater than 12°C and meat temperature no greater than 7°C [13]. This environmental issue was addressed by Pidrahíta, Punnett and Shahnavaz [14]. In this study it was shown that abattoir workers exposed to lower environmental temperatures had a higher prevalence of musculoskeletal symptoms, especially for low back, neck and shoulders. Whether these results were due to higher knife forces at lower temperatures or some other human physiological effect remain unclear.

Meat cutters have since long claimed that knife forces increase with lower meat temperatures which then implies higher musculoskeletal exposure at lower meat temperatures. Brown, *et al*. [15] investigated this and found that frozen meat implied higher cutting forces, and that forces also increased in fat, lean meat and connective tissue. However, the temperatures investigated were not within ranges normally found in the meat industry where carcasses are deboned within 24 hours after slaughter. The present study was performed to find out what effects the meat temperature has on cutting forces at 2, 7, 12°C, temperatures that are more likely to be found in a meat processing plant. In addition, the same issue was addressed for pure fat.

2. METHODS

2.1. Material

Whole parts of hind loin of pork and pure pork fat were collected at a deboning line. The air temperature at collection was 12°C and meat temperature was 7°C. These parts were put in insulated bags and transported within one hour to the laboratory where they immediately were further prepared. One hundred and forty four samples, 5 cm long, 4 cm wide and 2 cm thick were cut from the lean meat and also from the fat using aluminium cutting templates to ensure similar size of samples. Care was taken to align the muscle fibres to assure cuts perpendicular to the fibres. The samples were thermally insulated with four slabs of plastic foam, see Fig. (**1**) and were also individually wrapped in plastic film to ensure minimal loss of fluids. These samples were equally distributed into three refrigerators with temperatures 2, 7, 12°C and chilled more than 20 hours over night.

The temperature rise of the meat samples with applied insulation, taken from 7°C into room temperature was shown to be approximately 1°C/4 minutes in a pre-experimental test.

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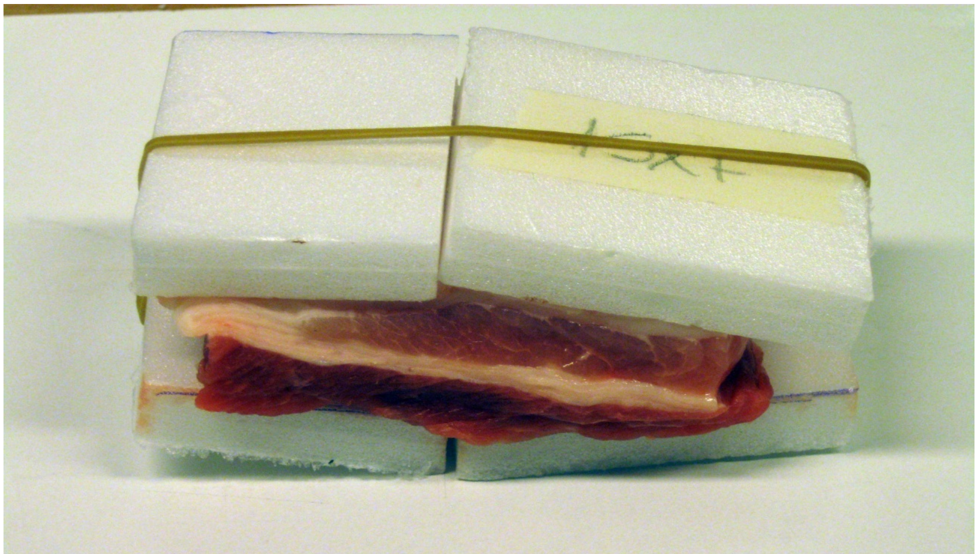

Fig. (1). Meat sample with plastic foam slabs. This photo originates from the pre-test series when not totally fat free meat samples were used. The temperature rise of the meat samples with applied insulation, taken from 7°C into room temperature was shown to be approximately 1°C/4 minutes in a pre-experimental test.

2.2. Equipment

A commercially available system for measuring knife sharpness (Anago) [16] was used for the study. A validation study of the methodology incorporated in this system has been previously reported [17]. The machine was directly connected to a computer with the Anago measurement software. The knife is normally run at constant speed through a standardized textile ribbon while the force exerted on the ribbon is recorded over time for knife sharpness analysis. For this investigation, the ribbon was replaced by a wooden fixture with a 10 mm wide slot where the knife could pass and where meat samples could be fixed (see Fig. **2**).

An aluminium frame inside the fixture guaranteed similar positioning for all samples. On one side of the slot the sample was also fixed by four nails penetrating the sample and the slabs while on the other side of the slot the sample could slide between the slabs.

The temperature in the refrigerators was measured by a probe in a glass of water. The probe was connected to a digital measurement system [18]. The glass was kept in the refrigerator, covered by a lid of aluminium to preserve temperature when the glass was taken out for temperature measuring and to prevent temperature drift due to water vaporisation. The temperature was checked several times during the measurements.

The knives were normal deboning knives of a well-known brand available in the market and were sharpened by the deboning company using the Cozzini knife sharpening system [19]. Knife sharpness was tested according to ordinary Anago procedures before and after the experiments.

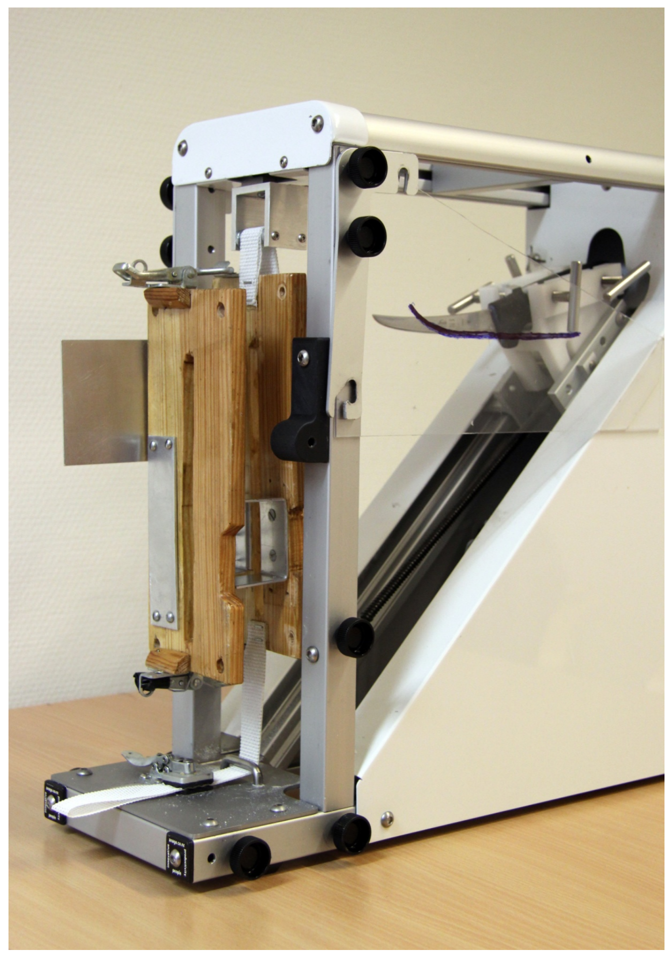

Fig. (2). The sharpness testing system pictured with the wooden fixture designed for the study. No meat is inserted in this photo but the knife is shown at the bottom/end position penetrating the 10 mm wide slot.

2.3. Protocol

Meat samples were taken from the refrigerators, one at the time. The plastic film was removed and the sample with its covers of plastic foam was positioned in the fixture, the two plastic foam slabs on the side without the fixating nails were retracted to expose the meat in the slot for the knife, the two parts of the wooden fixture were squeezed together by a drawbolt catch and the knife movement was started. The vertical forces exerted by the knife on the meat were automatically sampled by the Anago system. The total duration of a test cycle never exceeded 30 seconds. The room temperature in the laboratory was 21°C. The tests were made with alternating samples from the three temperature refrigerators to eliminate systematic effects due to gradually blunter knifes and the knife was changed every twenty-fourth sample for a newly sharpened one.

2.4. Evaluation

For each meat sample, the pre-tension of the ribbon holding the fixture was identified as an initial constant force, and this reading was subtracted from all force data. In all sample recordings the knife penetrates the meat/fat with a significant increase in force at approximately the same point on the knife blade and it takes about 60 mm of further knife travel to cut through the whole meat/fat sample, using the middle part of the knife blade. Force data starting from approximately 20 mm knife travel into the meat/fat and another 20 mm further on were averaged as an estimate of the force in that sample. An example of a force curve from one sample and the evaluation procedure is demonstrated in Fig. (**3**). For every temperature, there were 48 such estimates for both meat and fat.

2.5. Statistics

The number of meat samples was chosen based on a power estimate. Experience from a pre-test of the equipment indicated that the standard deviation (SD) of the force readings could be expected to be 2 N. To be able to significantly show a difference of 10% in force or larger with $p<0.05$, about 50 samples in each group were needed.

Differences between groups were tested with Student's two sided t-test. The effect sizes were shown by Cohen's d for independent groups, applying a pooled SD as standardizer and by graphical presentations of confidence intervals (CIs) for the group means [20].

3. RESULTS

The mean forces, SDs and CIs for the three temperatures, meat and fat respectively are shown in Table **1**.

As seen in Table **1**, forces for fat were about three times higher than for meat regardless of temperature. It is also seen that there were no significant differences in forces between temperature groups for meat and fat respectively except for fat at 2°C. These findings are also demonstrated by a Cohen's d >1 for fat at 2°C and the CI plots in Fig. (**4**).

4. DISCUSSION

The measurements show that there are no significant effects of temperature in the range 12-2°C except for fat where there was a strongly significant increase in force of about 30 percent when going from 7°C to 2°C. The increased forces needed in fat and the temperature dependence is consistent with the opinion among meat cutters that fat is much harder to cut and that very cold fat should be avoided. Our results are also consistent with those of Brown, *et al*. [15] who found higher forces in frozen beef and that fat, muscle membranes and connective tissues resulted in higher forces.

The temperature of the refrigerators varied ± 1°C during the experiments, and such minor variations would not be expected to have any significant effect on the results or conclusions. The rate of temperature rise in a meat sample with applied insulation slabs was tested before the

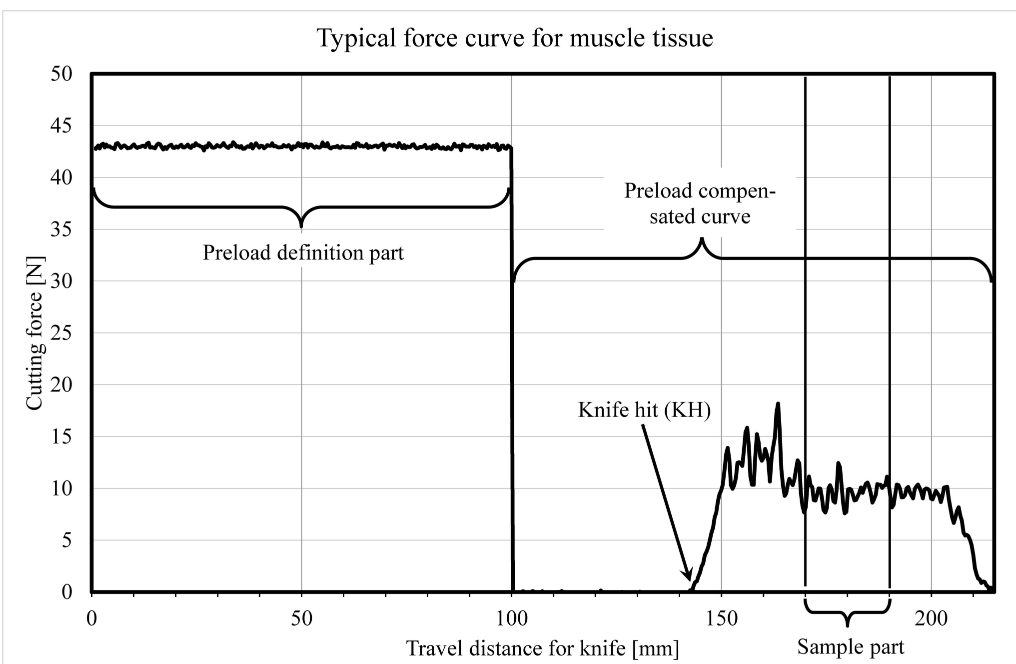

Fig. (3). An example of a force curve recorded by the ANAGO sharpness analyzer. The point where the knife stabs the meat sample is indicated (KH) and also the standardized part of the curve used for deducting a sample force average.

Table 1. Mean knife forces, standard deviations (SD), 95% confidence intervals (CI) at the three temperatures and corresponding t-tests for the comparison of different temperatures in lean meat and fat. All mean and SDs are based on 48 estimates. Cohen's d (effect size) was calculated for independent groups with a pooled SD as standardizer.

	Forces in N					
	Lean Meat			**Fat**		
	2°C	**7°C**	**12°C**	**2°C**	**7°C**	**12°C**
Mean	5,64	5,98	5,64	19,83	15,01	14,64
SD	1,58	2,05	1,80	5,87	3,38	2,70
95% CI	5,18 - 6,10	5,39 – 6,58	5,12 – 6,17	18,12 – 21,53	14,03 – 15,99	13,86 – 14,64
	t-Tests Lean Meat			**t-Tests Fat**		
Temp. groups°C	2 - 7	7 -12	2 - 12	2 - 7	7 -12	2 - 12
t-test p-values	0,37	0,40	0,99	<0.001***	0,56	<0.001***
Cohen's d				1,01		1,14

experiments at room temperature to be approximately 1°C/4 minutes. Since the whole procedure taking out the samples of the refrigerator, putting them into the fixture and perform the cut took about half a minute, the temperature rise was most likely to be negligible.

A SD of 2 N for meat, as estimated from the pre-test, proved to be reasonable (see Table **1**). The force levels in fat were about three times larger; SDs, however, were less than three times larger.

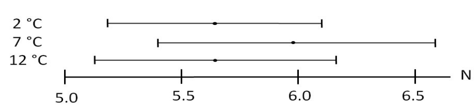

Fig. (4a). Graphic presentation of mean forces with 95% CIs at different temperatures in lean meat.

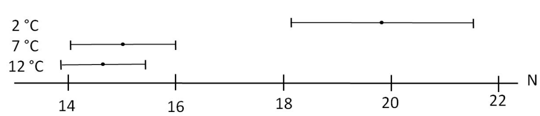

Fig. (4b). Graphic presentation of mean forces with 95% CIs at different temperatures in fat.

The present findings indicate an increase of cutting forces in fat when going from 7 to 2°C. It would be valuable to do further research to have more detailed knowledge about forces in this temperature range, and also below 2°C for both lean meat and fat.

The practical consequences of these findings is that cutting forces likely are increased at low temperatures in meat sections with high fat content while no such effect can be expected at low fat content. Furthermore, care should be taken not to chill the fat, which often is found at the surface of the carcass just under the skin, far below temperatures of 7°C. The temperature-related hardening of fat and subsequent increase in cutting forces observed at this temperature could ultimately result in greater exposures for industrial meat cutters in the performance of their work.

CONCLUSION

When lowering the temperature from 12 °C to 2°C, no differences in knife forces were found to cut lean pork meat. For pork fat there are no differences in the range 12-7°C while the knife force needed increases about 30% when lowering the temperature from 7 to 2°C.

CONFLICT OF INTEREST

The authors have no secondary interest that could influence the work that has been performed in this study.

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