The Critical Impact of Knife Sharpness on MSD Risk and Productivity in Meat Processing

Stefan Vosloo

Anago Limited, Hamilton, New Zealand

November, 2024

info@anagosharp.com

anago

ensure optimum sharpness

Table of Contents

Executive Summary

The meat processing industry faces significant challenges related to musculoskeletal disorders (MSDs), with prevalence rates 10 to 15 times higher than the general population. This white paper examines the critical role of knife sharpness in addressing these challenges, demonstrating its substantial impact on both MSD risk reduction and productivity enhancement.

Key Findings:

1. **MSD Prevalence**: Musculoskeletal disorders (MSDs) affect 67.2% to 93.5% of meat processing workers, who face MSD rates ten to fifteen times higher than the general workforce.
2. **Force Reduction**: Sharp knives can decrease cutting forces by up to 62.8% on average, significantly reducing physical strain on workers.
3. **Ergonomic Improvements**: Ergonomic improvements with sharp knives include a 10.3% reduction in mean grip forces, a 26.1% reduction in mean cutting moments, and a 21.9% decrease in peak cutting moments.
4. **Duty Cycle Impact**: Sharp knives can reduce duty cycles by 29.3%, increasing rest cycles by 22.4%
5. **MSD Risk Reduction**: Analyses using MAE, RULA, and OCRA frameworks consistently show that increasing knife sharpness moves tasks from high-risk to sustainable work zones.
6. **Productivity Gains**: In best-case scenarios, sharp knives can lead to a 160% increase in task completion over an 8-hour shift, without reducing rest cycles.

Implications:

1. **Worker Health**: Maintaining consistently sharp knives can significantly reduce the risk of MSDs, potentially decreasing worker compensation claims and associated costs.
2. **Operational Efficiency**: The substantial increase in productivity highlights the dual benefit of sharp knives in improving both worker safety and operational output.
3. **Economic Impact**: Reduced MSD prevalence and increased productivity can lead to significant cost savings and improved competitiveness for meat processing facilities.

Recommendations:

1. Implement objective knife sharpness measurement systems to ensure consistent, data-driven assessments.
2. Establish and enforce knife sharpness standards across all meat processing operations.
3. Invest in regular worker training on proper knife use, online edge maintenance, and the importance of knife sharpness.
4. Integrate knife sharpness assessments into knife sharpening systems and regular knife maintenance routines.
5. Adopt a holistic approach to MSD prevention, considering knife sharpness as a critical factor alongside other ergonomic interventions.

This white paper concludes that objective measurement and management of knife sharpness is not just beneficial, but essential for the meat processing industry. By prioritizing knife sharpness, facilities can create safer work environments, enhance productivity, and potentially realize significant cost savings. The evidence presented makes a compelling case for immediate action in implementing comprehensive knife sharpness management programs across the industry.

1. Introduction

Musculoskeletal disorders (MSDs) are a group of conditions affecting various components of the musculoskeletal system, including muscles, bones, nerves, and tendons. When brought about or aggravated by work demands, they are classified as Work-Related MSDs (WRMSDs). The prevalence of MSDs in meat processing is alarmingly high, with studies reporting that between 67.2% and 93.5% of workers experience discomfort in at least one body region (Tirloni et al., 2012; Sompan et al., 2024). The severity of this issue becomes clear when considering that the meat processing industry faces MSD rates ten to fifteen times higher than the general population (Chander et al., 2024). To put this in broader context, MSDs across all occupations globally account for 40% of compensation costs for occupational injuries and disorders (ILO, 2015). Given that the meat processing industry experiences MSD rates far above the average, it likely represents a disproportionate share of these costs, highlighting the critical need for intervention in this sector.

Meat processing workers are subject to numerous MSD risk factors, including repetitive actions, forceful exertion, high psychosocial work demands, awkward postures, cold temperatures, and inadequate hand tools (Da Costa and Vieira, 2010; Bevan, 2015). The work involves high loading intensities and cyclic repetitive muscle actions of the upper limbs (Dos Reis et al., 2018). Notably, 63% of injuries in a pork processing plant were associated with tasks requiring handheld tools (Cummings, 2014).

The economic impact of MSDs is substantial, affecting both worker health and operational efficiency. Research indicates that MSDs can diminish a worker's maximum strength, mobility, and speed, primarily due to pain (Harmse et al., 2016). Studies show that 50-61% of workers take pain medications to continue working (Tirloni et al., 2018; Tirloni et al., 2017), and absenteeism rates are significant, with 23% of workers reporting absences of at least one month (Mohammadi, 2012).

Despite the critical nature of knife work in this industry, the assessment of knife sharpness remains largely subjective. Workers often use knives until they perceive them as too dull, based on discomfort or perceived effort. However, this subjective approach may allow unsafe levels of cutting forces to persist, even when they feel acceptable to the user.

This white paper aims to demonstrate the critical impact of knife sharpness on MSD risk and productivity in meat processing. By objectively measuring and controlling knife sharpness, we can significantly reduce the risks of developing MSDs due to force application. Our analysis will quantify the relationship between knife sharpness and various ergonomic factors, showcase the potential for MSD risk reduction, and highlight the broader benefits of maintaining consistently sharp knives in the meat processing industry.

Through this data-driven approach, we seek to emphasize the importance of objective knife sharpness measurement and management, ultimately contributing to improved worker health and enhanced productivity in the meat processing sector.

2. The Science of Knife Sharpness and Its Impact

2.1 Definition of Knife Sharpness

In the literature, knife sharpness is defined as the total energy or force required to initiate a cut. Various methods have been proposed to measure this property:

McCarthy et al. (2007) proposed a laboratory measurement termed the Blade Sharpness Index (BSI). This method measures the total energy, or summation of force up to crack formation, by using an indentation cut into a soft polymer material by a straight-edged knife on one small part of the blade.

McGorry et al. (2005) further developed and evaluated a technique that allows for easy measurement of knife sharpness in the field, such as in meat processing plants, which was originally developed in McGorry et al., (2003). This method measures the force required to cut a mesh material along the entire length of a blade, providing a sharpness profile along the blade's length. The cutting of the mesh material showed a high correlation with cutting red meat (r=0.89). This approach is more advantageous and provides a more representative measurement of sharpness compared to McCarthy et al. (2007), which only measures a small portion of the blade.

Claudon and Marsot (2006) proposed a laboratory system to measure knife sharpness by driving the same point on the knife through a homogeneous foam rubber material at a constant velocity and angle. However, as pointed out by McGorry et al. (2003), a drawback of using a homogeneous material is that once the knife has initiated a cut, the blade geometry will interact with the material and cause crack propagation. This interaction may not give a representative measurement of sharpness, as it is not only the cutting edge interacting with the material.

This issue of crack propagation is arguably also present in the BSI method. Schuldt et al. (2016), in their validation study of the BSI, noted that the BSI measurement may be attenuated by friction forces, especially in low-friction material cases. This attenuation occurs because the method also cuts into a homogeneous material.

Given these considerations, the McGorry et al. (2005) method may be the most advantageous. It measures across the entire blade and utilizes a mesh material, where the force measurement of many tiny strands is conducted. This approach eliminates concerns with friction and crack propagation, purely measuring the force required for cut initiation.

2.2 Cutting Forces

Based on the definition of knife sharpness, it logically follows that sharpness decreases as cutting forces increase. This means that as a knife dulls, it becomes more difficult to cut, requiring more force to initiate a cut. Conversely, a sharper knife requires less force, making cutting easier.

Table 1 summarizes cutting forces encountered in meat processing plants, based on data from McGorry et al. (2003) and Karltun et al. (2016). The 'Reported Range' column shows the observed cutting forces in each study, demonstrating the variability in measurements. The 'Calculated Median' is derived by averaging the minimum and maximum values for each range, providing a central tendency measure for each study's observations. The 'Representative Value' has been calculated for this report to offer a single comparative figure for sharp and dull knives, calculated as the median between the lowest and highest calculated medians across both studies for each knife condition. This approach balances the data from both studies while accounting for the full range of reported values, resulting in representative values of 28.3 N for sharp knives and 76.0 N for dull knives. In these studies, sharp knives were freshly sharpened, while dull knives were classified as such by operators based on perceived effort.

Table 1 - Summary of Forces encountered in meat plants.

Knife Condition	Source	Reported Range [N]	Calculated Median [N]	Representative Value [N]
Sharp	McGorry et al. (2003)	13 – 15.6	14.3	28.3
	Karltun et al. (2016)	26.5 – 58	42.3	
Dull	McGorry et al. (2003)	18.5 – 35.3	26.9	76.0
	Karltun et al. (2016)	54.0 - 196	125	

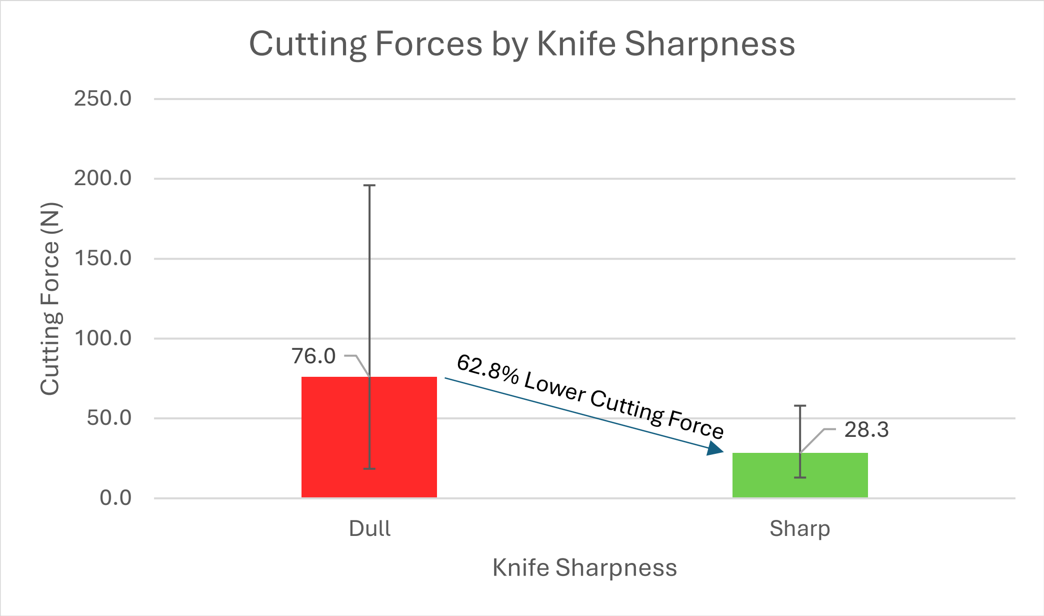

Figure 1 - Impact of Knife Sharpness on Cutting Forces in Meat Processing

Figure 1 visualizes the data from Table 1, illustrating the substantial difference in cutting forces between sharp and dull knives. The graph clearly demonstrates a 62.8% reduction in cutting force from dull to sharp knives, emphasizing the importance of knife maintenance. Key observations include:

1. **Median Forces:** Substantially higher forces are observed for dull knives (76.0 N) compared to sharp knives (28.3 N).
2. **Force Ranges:** A wider range of forces is observed for dull knives, indicating greater variability in cutting performance. The sharp knife range spans approximately 13 N to 58 N, while the dull knife range extends from about 18.5 N to 196 N.
3. **Range Overlap:** There is an overlap between the lower end of the dull knife range and the upper end of the sharp knife range. This overlap possibly highlights the subjective nature of knife sharpness assessment by workers and underscores the need for more objective measures.
4. **Extreme Cases:** The upper limit of the dull knife range (196 N) indicates that in extreme cases, workers might be exposed to cutting forces over 2.5 times the median value for dull knives. This raises serious ergonomic concerns, potentially exposing workers to harmful levels of force.
5. **Variability Across Plants:** The large spread and ranges in the data indicate significant variations in cutting forces across different meat processing plants. This suggests that factors beyond just sharpness (e.g., cutting technique, meat

type, worker experience) may influence the forces experienced. Additionally, knife sharpness is currently assessed subjectively, with knives being considered dull based solely on operator perception. Furthermore, without objective sharpness measurements during the sharpening process, sharpened knives will exhibit varying levels of sharpness both before and after sharpening, contributing to inconsistent performance.

The analysis demonstrates that maintaining sharp knives can reduce the required cutting force by approximately 62.8% in typical cases, with the potential for even greater reductions (up to 93.4%) in optimal conditions. However, the large spread observed for dull knives could indicate that workers use knives for extended periods before considering them dull. This suggests that workers may be exposed to high forces for prolonged durations.

From an ergonomic perspective, there may be a threshold of dangerous forces to which workers are exposed long before they themselves consider the knife to be dull. This prolonged exposure to increased loading on the wrists, hands, and joints could potentially increase the risk of musculoskeletal disorders (MSDs) and injuries. The variability in what workers consider "dull" further complicates this issue, highlighting the need for more standardized and objective measures of knife sharpness in meat processing environments.

The extreme case of 93.4% force reduction underscores the significant impact that optimal knife maintenance could have on worker safety and ergonomics. While achieving this level of reduction consistently may be challenging in practice, it sets a benchmark for the potential improvements in working conditions and efficiency that could be realized through rigorous and effective knife sharpening protocols and worker training.

2.3 Grip Forces and Cutting Moments

McGorry et al. (2003) conducted a field study investigating the effects of knife sharpness on the cutting moments and grip forces experienced by operators in meat processing. Figures 2, 3, and 4 illustrate the peak and mean cutting moments, as well as the mean grip forces for both sharp and dull knife conditions.

The study expressed these values in %MVC (Percent Maximum Voluntary Contraction). MVC, or Maximum Voluntary Contraction, refers to the maximum force that a person can voluntarily exert in a specific muscle or muscle group. %MVC is the percentage of this maximum force that is being used during a particular task. For example, a grip force of 50% MVC means the worker is using 50% of their maximum grip strength.

Using %MVC as a measure allows for standardized comparison across individuals with different strength levels and provides insight into the relative effort required for a task. Higher %MVC values indicate greater muscular effort and potential for fatigue or injury, particularly when maintained over extended periods.

Refer to Tables 2, 3 and 4 for an overview of the statistics. The medians were calculated in a similar fashion as the cutting forces section.

Table 2: Mean Grip Forces (%MVC) for Sharp and Dull Knives

Knife Sharpness	Median	Min	Max
Dull	29	24	34
Sharp	26	21	31

Table 3: Mean Cutting Moments (%MVC) for Sharp and Dull Knives

Knife Sharpness	Median	Min	Max
Dull	34.5	30	39
Sharp	25.5	22	29

Table 4: Peak Cutting Moments (%MVC) for Sharp and Dull Knives

Knife Sharpness	Median	Min	Max
Dull	128	118	138
Sharp	100	88	112

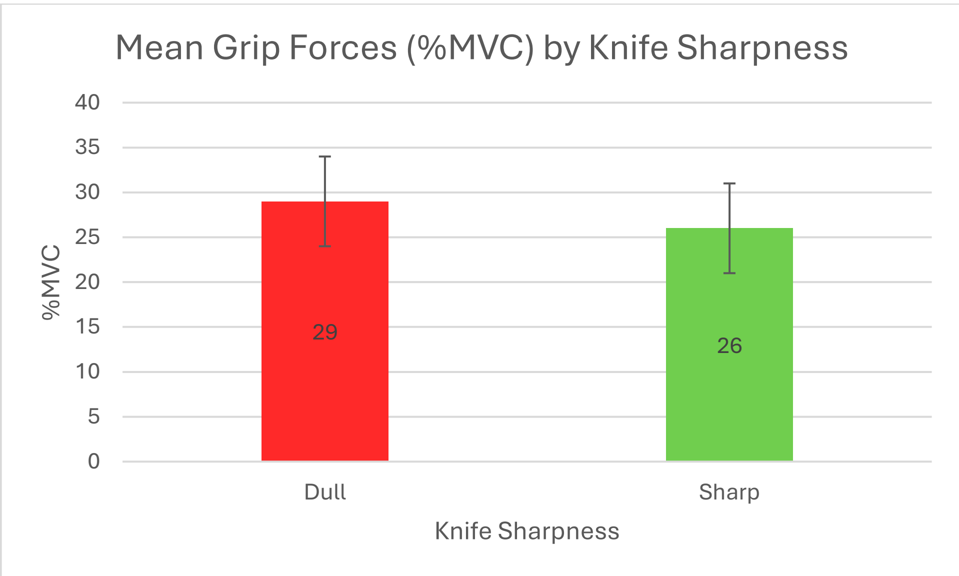

Figure 2: Mean Grip Forces (%MVC) for Dull and Sharp Knives in a Meat Processing Plant (McGorry et al., 2003)

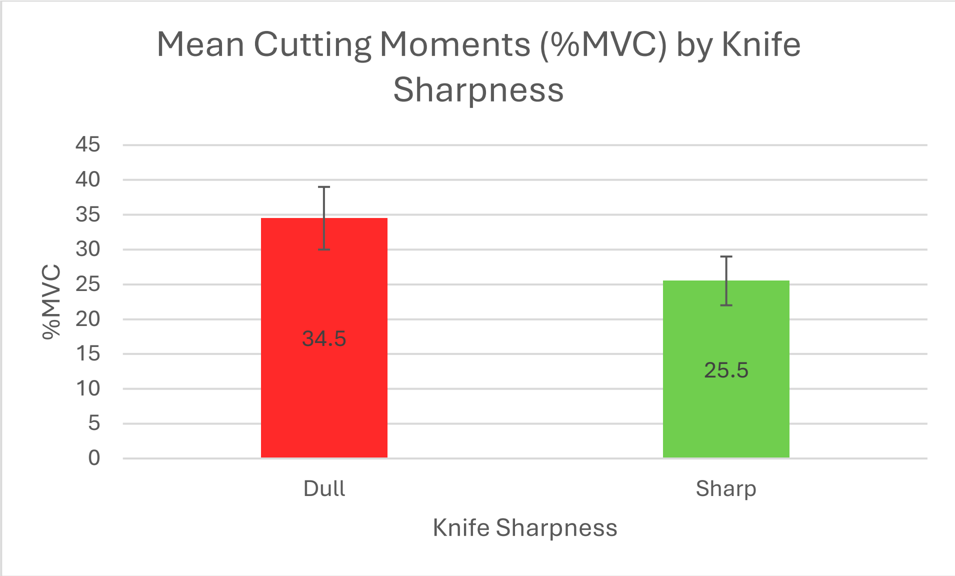

Figure 3: Comparison of Mean Cutting Moments (%MVC) Between Dull and Sharp Knives (McGorry et al., 2003)

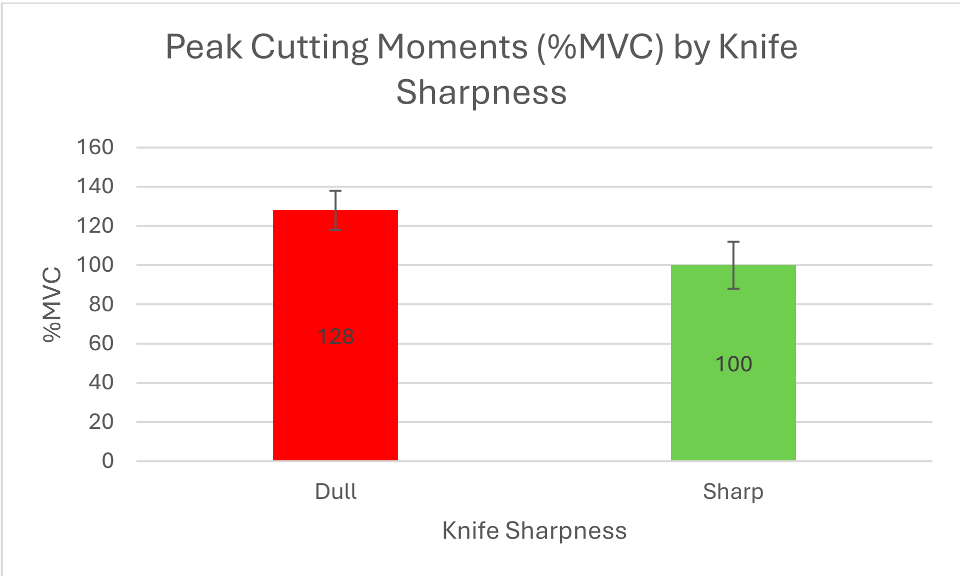

Figure 4: Peak Cutting Moments (%MVC) for Dull versus Sharp Knives (McGorry et al., 2003)

The study by McGorry et al. (2003) provides valuable insights into the relationship between knife sharpness and ergonomic factors in meat processing tasks. Figures 2, 3, and 4 illustrate the differences in mean grip forces, mean cutting moments, and peak cutting moments between sharp and dull knives, expressed as a percentage of Maximum Voluntary Contraction (%MVC).

Key findings from the data include:

1. Grip Forces (Figure 2):

- Mean grip forces decreased from 29% MVC for dull knives to 26% MVC for sharp knives, a 10.3% reduction.

2. Mean Cutting Moments (Figure 3):

- The most dramatic difference was noted here. 34.5% MVC (dull) to 25.5% MVC (sharp) was observed, representing a 26.1% reduction.

3. Peak Cutting Moments (Figure 4):

- A large difference was noted here, with a reduction from 128% MVC (dull) to 100% MVC (sharp), a 21.9% decrease.
- Wide ranges were observed: approximately 115-140% MVC for dull knives and 90-110% MVC for sharp knives, highlighting significant variability in peak force requirements.
- While peak exertions exceeding 100% MVC may seem counterintuitive, McGorry et al. (2003) suggest several explanations:
    - The peak cutting moments are impulse-like (forceful exertions of very brief duration) compared to the sustained isometric contractions used in MVC testing
    - During actual cutting tasks, workers may adopt postures more favourable for force generation than the constrained positions used in MVC testing

Additional biomechanical factors that could explain this phenomenon include:

- Dynamic movements during cutting can generate more force than static contraction as in MVC testing, due to added momentum.
- Workers may recruit additional muscle groups not typically involved in MVC testing.

These findings have several implications for musculoskeletal disorder (MSD) risk and prevention in meat processing environments:

Reduced Muscular Demands: The consistent reduction in %MVC across all measures indicates that sharp knives require less muscular effort overall. This reduction may delay the onset of fatigue, potentially allowing workers to maintain proper technique for longer periods and reducing the risk of fatigue-related injuries.

Safety Implications of Peak Forces: The ability to exceed MVC during cutting tasks represents significant risk moments for both acute injury and cumulative trauma. Even brief moments of excessive force can cause micro-trauma to tissues, and repeated exposure to forces exceeding MVC may accelerate MSD development. This makes maintaining knife sharpness particularly crucial, as sharp knives reduce the need for these extreme force applications.

Variability in Force Requirements: The ranges observed in all measures, particularly in peak cutting moments, suggest that while knife sharpness is crucial, individual technique and task variations also significantly impact force requirements. This variability highlights the need for comprehensive ergonomic interventions that address both tool maintenance and worker technique.

Long-term Health Implications: While the reductions might seem modest in short-term observations, the cumulative effect over months or years of work could be substantial in preventing or delaying the onset of MSDs. The data supports the hypothesis that maintaining sharp knives is a crucial factor in reducing the biomechanical risk factors associated with MSDs in meat processing work.

Ergonomic Intervention Potential: The significant reductions in force and moment requirements with sharp knives suggest that regular knife sharpening could be a cost-effective ergonomic intervention. This is particularly important given the potential for force peaks to exceed MVC, indicating that traditional ergonomic assessments based on MVC percentages may underestimate actual risk. Implementing and maintaining a rigorous knife sharpening protocol could be a key strategy in comprehensive MSD prevention programs in meat processing facilities.

However, the overlapping ranges, particularly in grip force and mean cutting moments, suggest that proper technique and individual factors also play important roles in force reduction. The wide ranges in peak cutting moments for both sharp and dull knives highlight the potential for high-force exertions regardless of sharpness, emphasizing the need for proper training and technique.

In conclusion, this study demonstrates clear ergonomic benefits of maintaining sharp knives in meat processing tasks, while also highlighting the complexity of factors influencing MSD risk. A holistic approach to MSD prevention, incorporating regular knife maintenance, worker training, and attention to individual techniques, is likely to yield the most significant long-term health benefits for workers in the meat processing industry. The consistent reduction in muscular demands associated with sharp knives underscores the importance of knife maintenance as a fundamental component of occupational health strategies in this sector.

2.4 Duty Cycle (DC) and Recovery Time

Knife sharpness plays a crucial role in reducing the physical demands of meat cutting tasks, which in turn affects duty cycles and recovery times, which are defined as follows:

Duty Cycle: The proportion of a work cycle spent actively performing a task, expressed as a percentage. Such as the time spent cutting meat and pulling and moving product.

Rest Cycle: The complementary proportion of a work cycle where the worker is not actively performing the primary task, allowing for brief recovery periods.

Calculation Method:

Duty Cycle (%) = (Cutting Time / Total Cycle Time) × 100

Rest Cycle (%) = 100 - Duty Cycle (%)

Duty cycle is important because repetitive actions and forceful exertions are risk factors for MSDs, and increasing the duration of applied force further increases this risk. Finneran & O'Sullivan (2010) reported a statistically significant relationship between duty cycle, musculoskeletal discomfort, and productivity, noting that productivity decreases with increased force and duty cycle.

McGorry et al. (2005) proposed a field measurement method for knife sharpness and conducted a study in a meat processing plant. Their findings revealed a significant mean reduction in cutting time of 29.2% when transitioning from dull to sharp knives during meat cutting tasks. This substantial decrease in cutting time has important implications for worker productivity and ergonomics.

Dempsey and McGorry (2004) investigated a pork shoulder deboning operation using an instrumented knife to measure various parameters, including cutting moments, grip forces, and cutting and cycle times. Using the mean cutting time and mean cycle time from their study, a representative duty cycle of 43.3% was calculated for demonstration purposes. The reduction in duty cycle was then applied based on the statistics from McGorry et al. (2005) mentioned above and used for the creation of Figure 5. Figure 6 was calculated based on the inverse of duty cycle, which equates to rest cycle. It's important to note that actual duty cycles can vary significantly depending on the specific meat cutting task, knife sharpness, and the skill of the operator.

Several studies have reported consistently high duty cycles in the meat processing industry, though values can vary widely depending on the specific task and muscle groups involved:

- Juul-Kristensen et al. (2002) and Arvidsson et al. (2012) reported duty cycles exceeding 98% for some muscle groups.
- McGorry et al. (2003) observed values ranging between 30% and 60%.

- Vogel and Eklund (2015) found duty cycles greater than 85%.

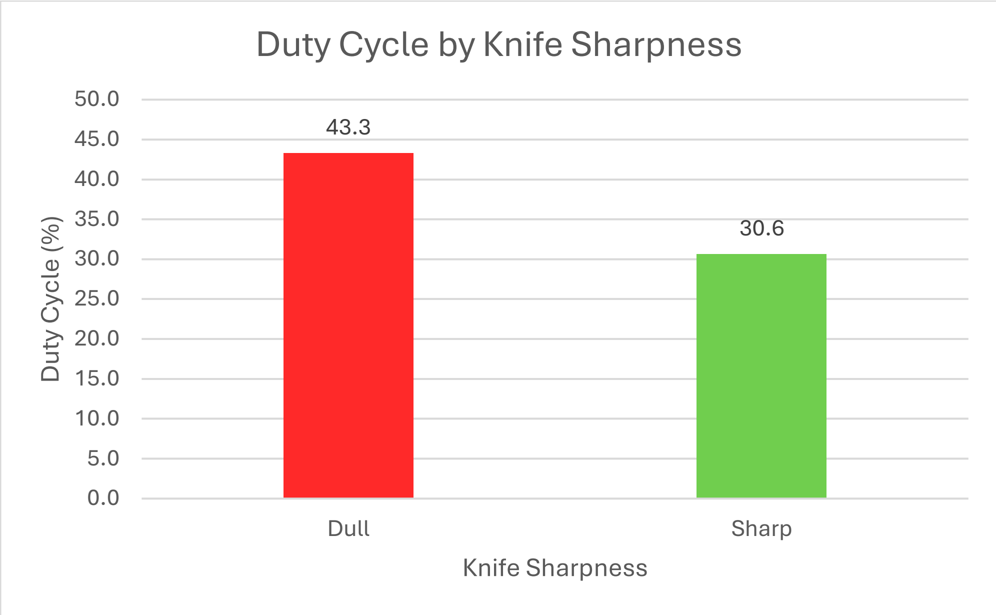

Figure 5: Average Reduction in Duty Cycle Achieved Through Improved Knife Sharpness

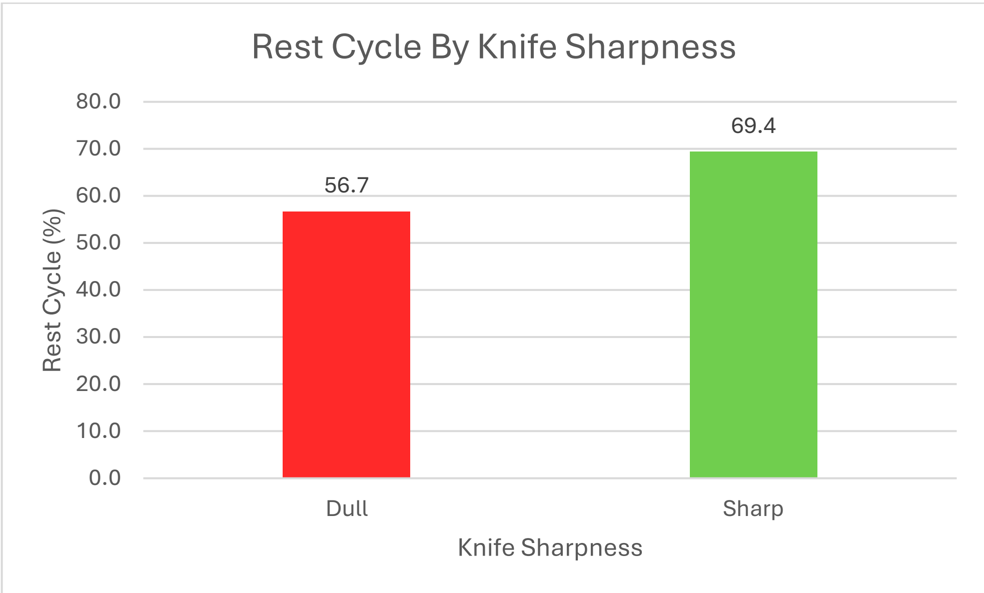

Figure 6: Rest Cycle Percentage Increase Associated with Sharp vs. Dull Knives

As illustrated in the graphs above, knife sharpness has a significant impact on both duty cycle and rest cycle:

1. **Duty Cycle Reduction**: Sharp knives lead to a notable decrease in duty cycle from 43.3% (dull knives) to 30.6% (sharp knives). This 29.3% reduction in duty cycle can

significantly lower the risk of musculoskeletal disorders (MSDs) by reducing the time workers spend actively cutting and applying stress to their hands, wrists and arms.

2. **Rest Cycle Improvement**: Conversely, the rest cycle increases from 56.7% with dull knives to 69.4% with sharp knives, representing a 22.4% improvement. This increased recovery time allows workers' muscles more opportunity to rest and recover between cutting tasks.

It is important to note that Figures 5 and 6 represent data for an individual worker. In a meat processing plant, the overall line speed or throughput is determined by the slowest member in the line. Consequently, when an individual worker's duty cycle reduces due to improved knife sharpness, their personal cycle time may not necessarily decrease. Instead, this efficiency gain typically translates into a larger rest cycle for that worker.

However, if the entire line speed increases, the dynamics change. In this scenario, workers may maintain the same absolute rest time but experience a reduced duty cycle percentage within a shorter overall work cycle. This distinction underscores the importance of considering both individual and system-wide factors when evaluating the impact of knife sharpness on worker ergonomics and productivity.

The observed improvements in duty cycle and rest cycle due to increased knife sharpness have several important implications:

1. **Reduced MSD Risk**: Lower duty cycles and increased rest times can significantly reduce the cumulative strain on workers' muscles, tendons, and joints, potentially lowering the risk of developing MSDs, as rest and duty cycle are important ergonomic factors (Potvin, 2012; Gibson & Potvin, 2016). Longer rest cycles provide workers with more frequent opportunities to recover, potentially reducing fatigue and improving overall job satisfaction.

2. **Improved Productivity**: Sharp knives not only reduce cutting time but also allow for more efficient work cycles, potentially increasing overall productivity without increasing line speeds. This is due to the decreased cutting effort. Even though sharper knives may only shave off a few seconds on each cycle, the cumulative time difference becomes large over a working day with thousands of cutting actions. For example, a 29.2% reduction in cutting time (McGorry et al., 2005) could translate to substantial time savings and productivity gains in a typical 8-hour shift.

In conclusion, the data clearly demonstrates that maintaining sharp knives in meat processing operations can lead to significant ergonomic benefits through reduced duty cycles and increased rest times. These improvements have the potential to enhance both worker health and operational efficiency, particularly when implemented systematically across the production line.

3. The Relationship Between Knife Sharpness and MSD Risk

To effectively demonstrate the impact of knife sharpness on musculoskeletal disorder (MSD) risk in meat processing, it's crucial to examine this relationship through the lens of established ergonomic assessment frameworks. This section will focus on three key frameworks: Maximum Acceptable Effort (MAE), Rapid Upper Limb Assessment (RULA), and Occupational Repetitive Actions (OCRA). By analysing these frameworks in the context of knife sharpness, we can illustrate how improved knife sharpness can significantly reduce MSD risk.

3.1 Rapid Upper Limb Assessment (RULA)

RULA is a widely used ergonomic assessment tool that focuses on the upper body, making it particularly relevant for evaluating meat cutting tasks. While RULA considers multiple factors, including posture, this analysis focuses primarily on the impact of force loading on the limbs.

Table 5 lists the assumptions that were used to calculate the RULA scores. Note that the postures at each step remained constant, with only the forces in Step 5 being varied. This ensures the impact of knife sharpness is not confused by postural changes.

Table 5 - Assumptions Used in RULA Calculations

RULA Step	Body Segment	Value
Constant Postures		
1	Upper Arm	20° - 45°
2	Lower Arm	60° - 100°
2a	Arms Across Midline	Yes
3	Wrist	15° - 15°
3a	Wrist Bent From Midline	Yes
4	Wrist Twisted From Neutral	Yes

5a	Repetition	Yes
6	Neck Position	10° - 20°
7	Trunk Position	0 - 20°
8	Legs and Feet Support	Yes
9	Resistance	Yes
Variable Factors		
5	Forces on wrist (Sharp)	<2 kg, repetitive force
5	Forces on wrist (Dull)	2 - 10 kg, repetitive force

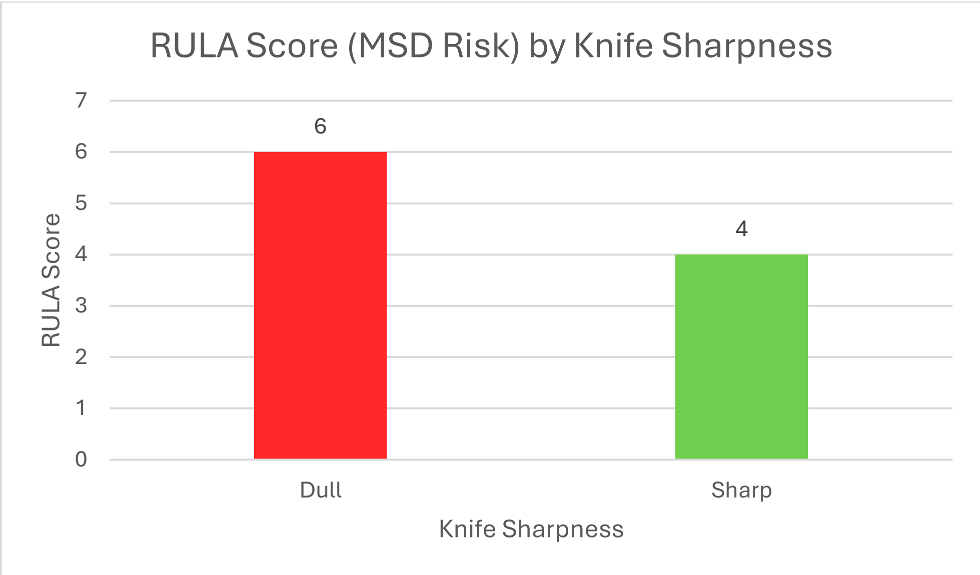

Figure 7: RULA Score (MSD Risk) by Knife Sharpness

Analysis of Figure 7:

1. **Risk Reduction:** The RULA score decreases from 6 (dull knife) to 4 (sharp knife), representing a significant reduction in MSD risk.
2. **Interpretation of Scores:**
    - A score of 6 indicates that further investigation and changes are required soon.
    - A score of 4 suggests that further investigation is needed, and changes may be required.

3. **Practical Implications:** While a score of 4 still indicates some risk, the reduction from 6 to 4 represents a meaningful improvement in worker safety and comfort.

It's important to note that these RULA scores were calculated assuming constant posture and varying only the force loading on the wrists. This isolates the impact of knife sharpness on MSD risk.

3.2 Occupational Repetitive Actions (OCRA)

The OCRA (Occupational Repetitive Actions) method provides a systematic approach to assessing biomechanical overload risk of the upper limbs during repetitive tasks. As suggested in ISO and CEN biomechanical standards, this method offers assessment tools at varying levels of detail, with the OCRA Checklist serving as an initial screening tool for mapping workplace risk levels.

Three of the primary risk factors that contribute to the overall assessment include force, frequency, and recovery factors. The force factor evaluates the muscular effort required during technical actions, utilizing the Borg CR-10 scale to measure perceived exertion. The frequency factor examines the repetitive nature of the work by measuring the number of technical actions performed per minute. The recovery factor assesses the presence and distribution of adequate rest periods throughout the work shift and acts as a multiplier in the final risk calculation.

See the formula for the OCRA Checklist below:

$$(FF + FFz + FP + FC) \times RM \times DM = OCRA\ Score \quad (Colombini\ et\ al., 2013)$$

Where,

FF = Frequency Factor, **FFz** = Force Factor, **FP** = Posture Factor, **FC** = Additional Risk Factor, **RM** = Recovery Multiplier, **DM** = Duration Multiplier

For a comprehensive understanding of all factors included in the OCRA method, including posture and additional risk factors, refer to Colombini et al. (2013), which provides detailed explanations of the complete assessment methodology and its practical application.

Table 6 - Summary of Average OCRA Scores and Risk Distribution of Musculoskeletal Disorders Across Different Studies in Meat and Poultry Processing Industries

Study	Average OCRA Score (Risk Level)	High-Risk Tasks (%)	Moderate-Risk Tasks (%)	Low-Risk Tasks (%)
(Dos Reis et al., 2015)	18.3 ± 2.7 (Moderate Risk)	8%	81%	11%
(Dos Reis et al., 2018)	22.2 ± 7.7 (Moderate Risk)	27%	73%	-
(Dos Reis et al., 2019)	20.6 ± 5.8 (Moderate Risk)	11%	89%	-
(Dos Reis et al., 2020)	18.9 ± 4.2 (Medium Risk)	6%	94%	-

To illustrate typical OCRA risk levels in meat processing, a mean score was calculated across these studies. While actual scores may vary significantly based on specific tasks, conditions, and facilities, this calculation provides a useful reference point for discussion. The derived mean OCRA score of 20.0 serves as a demonstrative example of potential risk levels in the industry. Table 7 provides the interpretative framework for understanding this score's implications, though it should be noted that individual workplace assessments may yield different results based on their specific circumstances.

Table 7 - Interpretation of OCRA Checklist Points and Corresponding Incidence Rates of Work-Related Musculoskeletal Disorders (WSMDs). (Dos Reis et al., 2015)

Risk	OCRA Score	Incidence of WSMDs (%)
Acceptable	< 7.5	< 5.26
Borderline / Very Low	7.6 – 11	5.27 – 8.35
Low	11.1 – 14	8.36 – 10.75
Moderate	14.1 – 22.5	10.76 – 21.51
High	> 22.5	> 21.51

The OCRA method provides valuable insights into the relationship between knife sharpness and MSD risk in meat processing. Analysis of multiple studies, as seen in Table 6, reveals consistent patterns of risk across the industry. The mean OCRA score of 20.0 across studies places the majority of workers in the moderate risk category, indicating an MSD incidence rate of 10.76% to 21.51%. This translates to approximately 11-22 workers per 100 developing MSDs. More concerning, some tasks were classified as high-risk (6-27% of tasks across studies), where MSD incidence rates exceed 21.51%.

Tirloni et al. (2020) demonstrated that knife sharpness significantly impacts OCRA risk scores, see Figure 8 below.

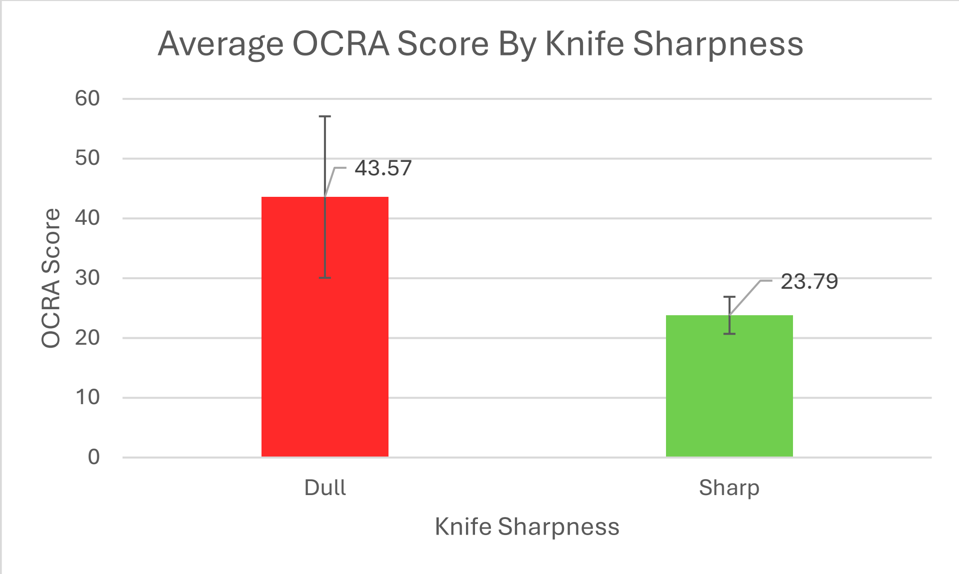

Figure 8 - Average OCRA score across different knife conditions.

Figure 8 reveals a substantial difference in risk levels between dull and sharp knives. The data shows an average reduction in MSD risk level of 45.4% when using sharp versus dull knives, with potential reductions of up to 63.75% under optimal conditions.

However, this study has several limitations. The primary concern is the use of the Borg Scale to calculate the OCRA force factor. The Borg Scale relies on workers' subjective perception of effort during task execution. Furthermore, the classification of knives as "well-sharpened" or "poorly sharpened" was based solely on workers' subjective assessment of cutting performance. As demonstrated earlier in this report, subjective assessments result in significant variability in what constitutes both sharp and dull knives, with even greater variation observed in dull knife classifications.

Consequently, OCRA scores could differ significantly if calculated using objective measurements of both knife sharpness and force application (%MVC) rather than subjective assessments.

The force factor calculation requires measuring applied force using either perceived effort or %MVC on a scale of zero (no effort) to ten (maximum effort), categorized as follows:

- Low Force: 0-2
- Moderate Force: 3-4
- Intense Force: 5-7
- Near Maximum Force: 8-10

While Ergonautas (n.d.) suggests that forces below moderate are not considered in calculations, this represents a simplified approach. For a more comprehensive understanding of force factor calculations, refer to Colombini et al. (2013).

Table 8 - OCRA force factor calculation (Ergonautas, n.d.)

Moderate Force		Intense Force		Near Maximum Force	
Duration	**Points**	**Duration**	**Points**	**Duration**	**Points**
1/3 of the time	2	2 sec. every 10 min.	4	2 sec. every 10 min.	6
50% of the time	4	1% of the time	8	1% of the time	12
> 50% of the time	6	5% of the time	16	5% of the time	24
Almost all the time	8	> 10% of the time	24	> 10% of the time	32

Knife sharpness significantly impacts the OCRA score through multiple pathways, affecting not only force requirements but several other risk factors simultaneously.

Force Factor Impact: Sharp knives reduce cutting forces by 62.8% on average, as previously documented. This corresponds to approximately a 30% reduction in %MVC. Such reductions dramatically affect OCRA scoring. For example, consider a worker experiencing intense force (50-70% MVC) with a duty cycle exceeding 50%, resulting in a score of 24 (refer to Table 8). Sharpening the knife reduces %MVC by 30%, shifting the task into the low-to-moderate force category. Combined with the documented 29.3% reduction in duty cycle, which brings the worker below the 50% threshold, the final score drops to 2-4 points. This represents an 80% or greater reduction in the force factor under certain conditions.

Frequency and Recovery Benefits: The frequency factor improves through reduced cutting time and decreased duty cycle, leading to lower repetitive strain. Workers struggling with dull knives often have minimal rest opportunities due to production demands. In contrast, sharp knives enable reduced cutting times, allowing workers to incorporate more frequent rest periods. These additional rest cycles provide enhanced opportunities for muscle recovery between cutting actions, improving recovery factors.

Overall Risk Reduction: These combined improvements yield a substantial reduction in OCRA risk scores, with potential for even greater reductions under optimal conditions. While sharp knives alone cannot eliminate all ergonomic risks, their significant impact across multiple risk factors establishes knife sharpness maintenance as an essential component of comprehensive MSD prevention strategies in meat processing operations.

See Table 9 for an analysis on the possible risk reduction from improved knife sharpness.

Table 9 - OCRA Score Improvement Due to Improved Knife Sharpness

Risk Factor	Component	Dull Knife	Sharp Knife	Change	Justification / Assumption
Frequency	Action/min	62.5-67.4	62.5-67.4		Using frequencies reported in Tirloni et al., (2020).
	Score	9	8	-11%	Almost no rest with dull knife, with some rest possible with sharp knife.
Force	Borg Scale	5-7	2-4	-75%	Reduction in %MVC by 30% from dull to sharp.
	Score	24	2	-92%	From OCRA force table for duration and intensity (Table 8)
Posture	Shoulder	4	3	-25%	Reduced exposure time due to lower duty cycle
	Elbow	4	3	-25%	Reduced exposure time due to lower duty cycle
	Wrist	4	3	-25%	Reduced exposure time due to lower duty cycle
	Hand Grip	8	6	-25%	Reduced exposure time due to lower duty cycle
	Posture Score	*8*	6	*-25%*	Highest value among joints
Additional Factors	Machine Paced	2	2	0%	No change - production line speed constant.
Recovery	Multiplier	1.265	1.16	-8.3%	1 hour break, plus amount of non-cutting time per shift calculated from Figure 12), 8-hour shift.
Duration	Multiplier	1.0	1.0	0%	Based on 8-hour shift
Final OCRA Score		**54.4**	**20.88**	**-61.6%**	(Freq + Force + Post + Add) × Rec × Dur
Risk Level		High	Medium	Improved	Based on OCRA risk classification

The analysis demonstrates a 61.6% reduction in MSD risk as measured by the OCRA score when comparing sharp versus dull knife conditions. This risk reduction exceeds the average reduction of 45.4% observed in Figure 8, likely for two key reasons. First, previous studies may not have fully accounted for the cascading effects of knife sharpness on duty cycle and recovery factors. Second, the subjective nature of sharpness assessment in these studies, compared to objective measurements, may have led to underestimation of the full benefits of truly sharp knives. Tirloni et al. (2020) found that the impact of knife sharpness on OCRA scores varies considerably across different meat cutting operations, with risk increases due to dull knives ranging from 0% to 137.5% (see Figure 8). The substantial risk reductions observed, whether using conservative estimates from previous studies or the more comprehensive assessment presented here, underscore the critical importance of implementing systematic knife maintenance programs as a fundamental component of occupational health and safety in meat processing facilities.

3.3 Maximum Acceptable Effort (MAE) Model

The MAE model, developed by Potvin (2012), provides a quantitative approach to assessing the risk of MSDs based on the relationship between force exertion and duty cycle. This model is particularly relevant to meat processing tasks, where workers often engage in repetitive cutting actions over extended periods.

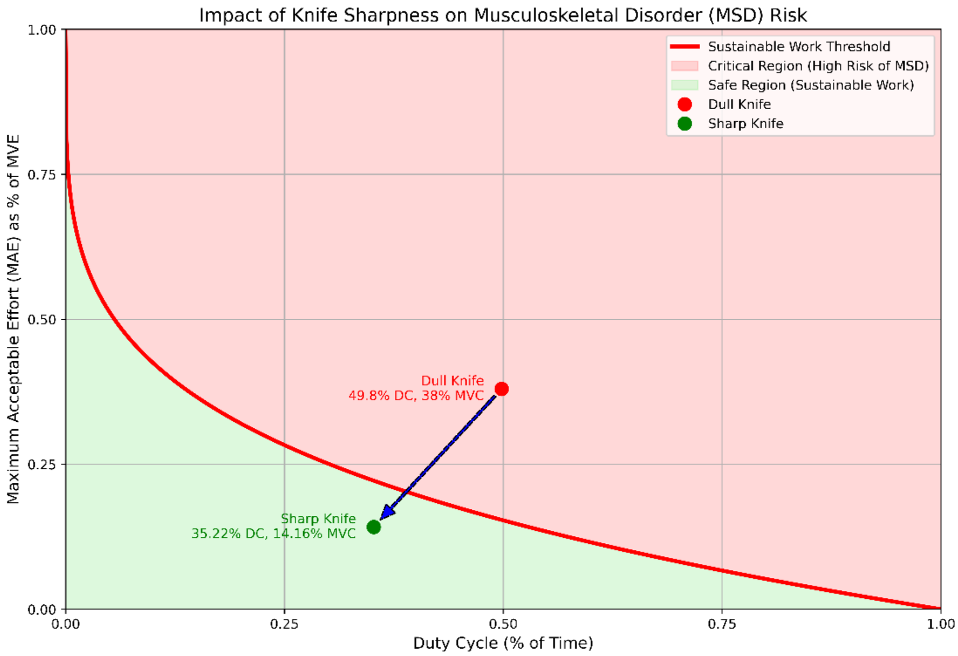

Figure 9: Impact of Knife Sharpness on Musculoskeletal Disorder (MSD) Risk

Analysis of Figure 9:

1. **Dull Knife Scenario:** With a dull knife, workers operate at a 49.8% duty cycle and 38% Maximum Voluntary Contraction (MVC). This places them well above the sustainable work threshold, indicating a high risk of developing MSDs.

2. **Sharp Knife Scenario:** Improved knife sharpness reduces the duty cycle to 35.2% and the MVC to 14.2%. This significant shift moves the work into the safe region, below the sustainable work threshold.
3. **Force Reduction:** The sharp knife scenario demonstrates a 62.8% reduction in force required, as evidenced by the decrease in MVC from 38% to 14.2%.
4. **Duty Cycle Improvement:** The duty cycle shows a 29.3% reduction, from 49.8% to 35.2%, indicating less time spent in active cutting.

These results strongly support the hypothesis that increasing knife sharpness can substantially reduce MSD risk by lowering both the force required and the duty cycle of cutting tasks.

3.4 Discussion

The analysis across these ergonomic frameworks consistently supports the hypothesis that increasing knife sharpness reduces the risk of MSDs:

1. **Force Reduction:** All three frameworks consider force as a critical factor. The significant reduction in force required with sharper knives (62.8% in our MAE analysis) directly translates to lower MSD risk across all assessment methods.
2. **Duty Cycle Improvement:** The 29.3% reduction in duty cycle demonstrated in the MAE analysis not only improves the MAE score but would also positively impact OCRA assessments and potentially influence RULA scores through reduced cumulative strain.
3. **Risk Zone Transition:** Perhaps most compellingly, the MAE analysis shows that improved knife sharpness can move a task from a high-risk zone to a sustainable work zone, a dramatic improvement in worker safety.
4. **Consistent Risk Reduction:** The RULA score reduction from 6 to 4, while focused solely on force loading, aligns with the overall risk reduction seen in the MAE analysis, providing corroborating evidence from a different assessment perspective.

In conclusion, the multi-framework analysis presented here provides robust support for the hypothesis that increasing knife sharpness in meat processing tasks can significantly reduce the risk of MSDs. By addressing key risk factors such as force exertion and duty cycle, sharper knives contribute to a safer, more sustainable work environment. While this analysis focused primarily on force loading to isolate the impact of knife sharpness, it's important to note that a comprehensive MSD prevention strategy would also consider other factors such as posture and workplace design.

4. The Impact of Knife Sharpness on Productivity

4.1 Overview of the Study

This section analyses the impact of knife sharpness on productivity in meat processing tasks, based on data from Dempsey & McGorry (2004). A theoretical model was created to demonstrate how improvements in knife sharpness can significantly affect work cycles and overall productivity.

4.2 Methodology and Calculations

The graph was generated using a combination of data from the original study and extrapolated values based on previously established improvements in cutting time. Four scenarios were modelled:

- Dull Knife (Worst-Case): The longest cycle time and cutting time reported in the study was used to calculate the metrics of this category.
- Average Dull Knife: Calculated using the mean cutting time and cycle time from the study, representing typical performance with a dull knife.
- Average Sharp Knife: Derived by applying the mean cutting time improvement of 29.2% (reported by McGorry et al., 2005) to the Average Dull Knife metrics.
- Sharp Knife (Best-Case): The shortest cycle time and cutting time reported in the study was used to calculate the metrics of this category.

Calculations included:

- **Cycle Time (s) = Cutting Time (s) + Rest Time (s)**
  - Represents the total time for one complete work cycle, including both the active cutting phase and recovery period.
  - Example: If cutting takes 15 seconds and rest takes 5 seconds, cycle time is 20 seconds.
- **Duty Cycle (%) = (Cutting Time / Cycle Time) * 100**
  - Expresses the percentage of the total cycle spent actively cutting.
  - Example: With 15 seconds cutting in a 20-second cycle, duty cycle is (15/20) * 100 = 75%
- **Tasks per Hour = 3600 seconds / Cycle Time (seconds)**
  - Calculates how many complete cutting cycles can be performed in one hour

- Example: With a 20-second cycle time, tasks per hour is 3600/20 = 180 tasks

- **Tasks per Shift = Tasks per Hour * 8 (assuming an 8-hour shift)**
  - Estimates the total number of cutting cycles possible in a full work shift.
  - Example: At 180 tasks per hour, tasks per shift is 180 * 8 = 1,440 tasks

The graph below visualizes work cycles across four knife conditions, ranging from worst-case dull to best-case sharp. Each pair of red and green represents one complete work cycle, where red sections indicate active cutting time and green sections show rest periods (non-cutting time). The metrics for each condition are displayed on the right side, including cycle time, cutting time, duty cycle, tasks per hour, and tasks per shift. By reading from top to bottom, one can observe how knife sharpness influences these parameters. This visualization provides a clear representation of how work cycles change with knife condition, allowing for direct comparison of cutting and rest periods across different scenarios.

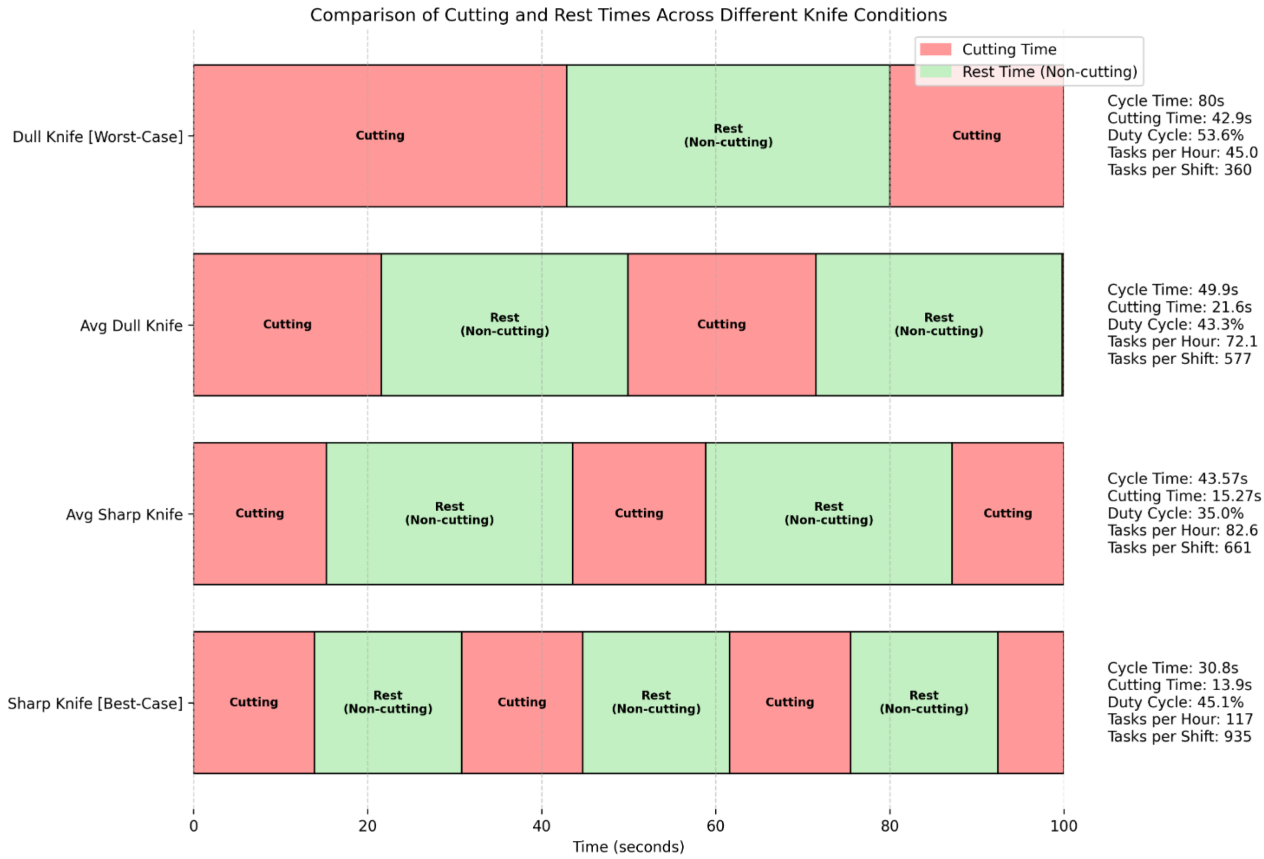

Figure 10 - Productivity Statistics Across Different Knife Conditions

The above graph visually represents the cycle times for each knife condition, clearly showing the proportion of cutting time (red) to rest time (green) within each cycle.

Key observations:

1. **Cycle Time Reduction:** From the worst-case dull knife (80s) to the best-case sharp knife (30.8s), we see a dramatic 61.5% reduction in cycle time.
2. **Duty Cycle Improvement:** The duty cycle decreases from 53.6% (worst-case dull) to 40.1% (best-case sharp), indicating less time spent in active cutting.
3. **Productivity Increase:** Tasks per hour increase from 45 (worst-case dull) to 117 (best-case sharp), representing a 160% productivity boost.
4. **Cumulative Impact:** Over an 8-hour shift, the difference is stark: 360 tasks are completed with the worst-case dull knife versus 935 tasks with the best-case sharp knife. Not only do sharp knives enable more completed tasks, but they also increase the percentage of rest time. From worst-case to best-case sharpness, the percentage of rest (non-cutting) time per cycle increases from 46.4% to 54.9%, representing an 18.31% improvement. Cumulatively, over an 8-hour shift, a worker experiences a 16.0% reduction in cutting time and an 18.4% increase in rest time, despite completing more tasks. See Figure 10 below for per hour productivity statistics.
5. **Average Improvement:** Even when comparing average dull to average sharp knives, significant improvements are evident: a 14.6% increase in tasks per shift (from 577 to 661) and a 19.2% reduction in duty cycle.

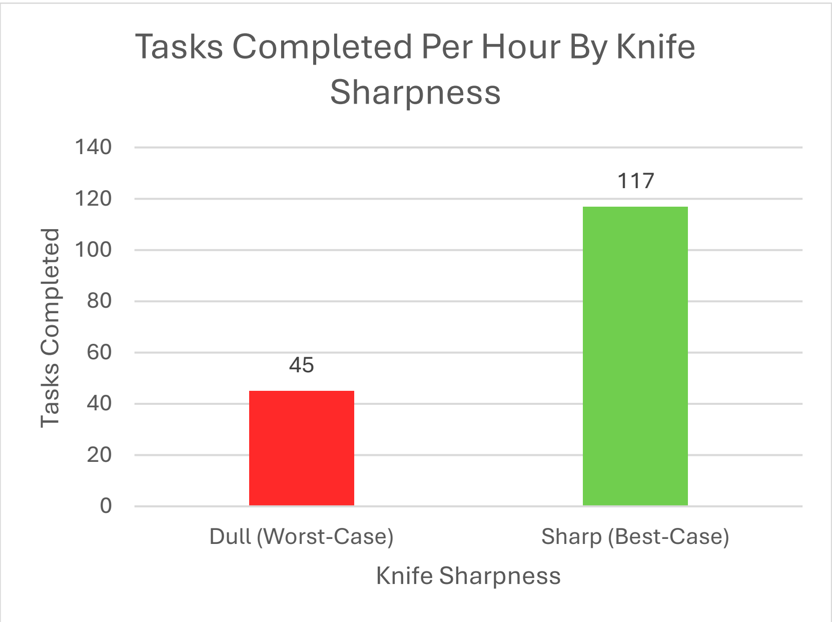

Figure 11 - Best Case Tasks Completed Per Hour by Knife Sharpness

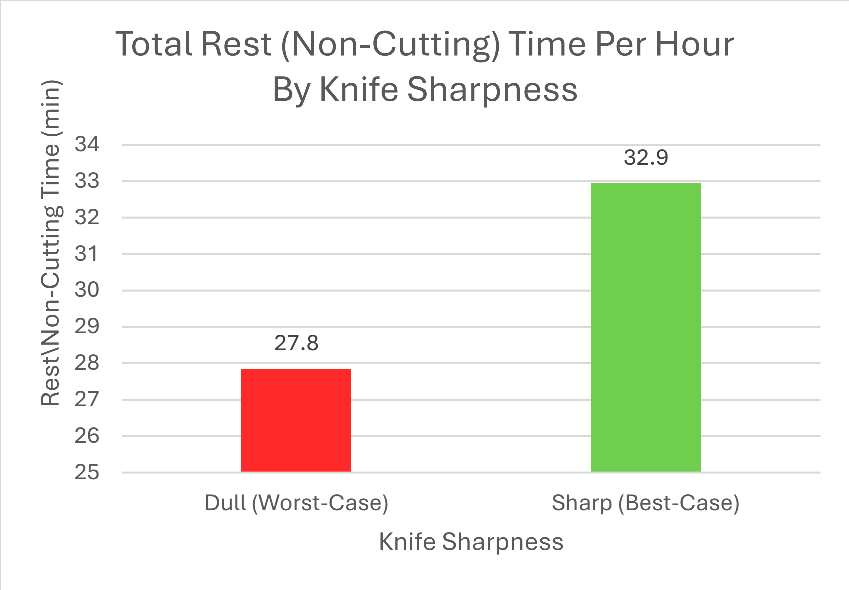

Figure 12 - Best Case Total Rest (Non-Cutting) Time Per Hour

4.3 Discussion

These results demonstrate the substantial impact that knife sharpness can have on productivity in meat processing tasks. While the improvement in cutting time for a single task may seem small (e.g., from 21.6s to 15.2s for average knives), the cumulative effect over thousands of repetitions during a shift is dramatic.

It's crucial to note that these calculations are theoretical and based on extrapolations from real-world data. Factors such as operator skill, fatigue, and variations in meat composition could influence actual results. The stark difference between worst-case and best-case scenarios may incorporate some level of operator skill variation in addition to knife sharpness.

4.3.1 Systemic vs. Individual Improvements

The productivity gains shown in Figure 10 assume that the entire production line experiences an increase in knife sharpness. In this scenario:

1. **Whole Line Speed Increase:** If all workers consistently use sharper knives, the entire line's speed can increase. This would lead to the productivity improvements demonstrated in the graph.
2. **Constant Rest Time:** It's important to note that in this case, the absolute rest time (non-cutting time) would likely remain constant. These periods often include tasks like product handling or positioning, which are not directly affected by knife sharpness.

3. **Changed Duty Cycle:** With increased line speed, the duty cycle and overall cycle time would change, but the absolute rest period would remain the same. This explains why Figure 10 shows a reduction in the proportion of rest time as knife sharpness improves.

However, if knife sharpness is improved for only one individual in the line:

1. **Constant Line Speed:** The overall line speed would still be limited by the slowest member. In this case, the individual's total cycle time would remain the same.
2. **Increased Rest Time:** The worker with the sharper knife would complete their cutting tasks faster, resulting in an increased rest cycle within the same overall cycle time.
3. **Ergonomic Benefits:** This scenario, while not improving overall productivity, still offers significant benefits. The increased rest time allows for better fatigue recovery and potentially reduces the risk of musculoskeletal disorders (MSDs).

4.3.2 Implications of Different Scenarios

1. **Systemic Improvement:** Implementing sharp knives across the entire line can lead to substantial productivity gains, as shown in the graph. However, care must be taken to ensure that increased line speeds do not negate the ergonomic benefits of sharper knives.
2. **Individual Improvement:** Even when overall productivity doesn't increase, individual improvements in knife sharpness can significantly enhance worker well-being through increased rest periods.
3. **Balanced Approach:** The ideal scenario would be a systemic improvement in knife sharpness, coupled with careful management of line speeds to maintain adequate rest periods. This could potentially offer both productivity gains and ergonomic benefits.

These considerations highlight the complexity of implementing changes in a production line environment. While the potential for productivity improvements is clear, it's essential to approach such changes holistically, considering both system-wide effects and individual worker impacts. The goal should be to optimize both productivity and worker safety, recognizing that these factors are often interrelated in complex ways.

5. Synthesis of findings

This white paper has examined the critical impact of knife sharpness on musculoskeletal disorders (MSDs) and productivity in the meat processing industry. The synthesis of the findings reveals several key points.

5.1 Prevalence and Significance of MSDs in Meat Processing

1. *High Prevalence:* Studies show that 67.2% to 93.5% of meat processing workers experience discomfort, a symptom of MSDs, in at least one body region. MSD rates in the meat processing industry are 10-15 times higher than those in the general population.
2. *Economic Impact:* Across all occupations globally, MSDs account for 40% of compensation costs for occupational injuries and disorders. Given the exceptionally high prevalence of MSDs in meat processing, this industry likely represents a substantial portion of these costs, creating a significant economic burden.

5.2 Knife Sharpness and Its Effects

1. *Force Reduction:* Sharp knives can reduce cutting forces by up to 62.8% compared to dull knives, significantly decreasing the physical demands on workers.
2. *Grip Forces and Cutting Moments:* Sharp knives lead to:
   - 10.3% reduction in mean grip forces
   - 26.1% reduction in mean cutting moments
   - 21.9% decrease in peak cutting moments
3. *Duty Cycle Improvement:* Sharp knives can reduce duty cycles by 29.3%, increasing rest cycles by 22.4%, allowing more time for muscle recovery.

5.3 Knife Dulling Dynamics

1. *Rapid Deterioration:* Studies show that knife sharpness deteriorates significantly during a single shift. A study by Savescu et al., (2018) demonstrated that knife sharpness reduced by 0.72N for every 1% of time spent cutting. Karltun et al. (2016) reported a sharpness decrease of 24.51 N – 30.52 N per hour. There results show that once-per-shift sharpening is inadequate. Knives should not only be sharpened at the start of a shift, but should be maintained throughout the shift.

2. *Progressive Impact:* As knives dull throughout the shift:
    - Cutting forces progressively increase
    - Workers must exert more effort
    - MSD risk escalates as the shift progresses
3. *Cumulative Effects:* The combination of increasing force requirements and accumulated fatigue creates a particularly high-risk situation in the latter portions of work shifts.

5.4 Impact on MSD Risk

1. *RULA Assessment:* Knife sharpness can reduce RULA scores from 6 (requiring immediate changes) to 4 (needing further investigation), indicating a significant reduction in MSD risk.
2. *OCRA Considerations:* Sharp knives positively impact OCRA assessments by reducing technical actions, force requirements, and potentially increasing recovery periods.
3. *MAE Model:* Sharp knives move tasks from high-risk zones to sustainable work zones, dramatically improving worker safety.

5.5 Productivity Implications

1. *Cycle Time Reduction:* Sharp knives can reduce cycle times by up to 61.5% in best-case scenarios.
2. *Task Completion:* Over an 8-hour shift, workers could potentially complete 935 tasks with the sharpest knives compared to 360 tasks with the dullest knives, a 160% increase in productivity.
3. *Average Improvement:* Even comparing average dull to average sharp knives shows a 14.6% increase in tasks per shift (577 to 661).

5.6 Limitations of Current Practices

1. *Subjective Assessment:* Relying on workers to determine when knives are dull can lead to prolonged use of suboptimal tools, increasing MSD risk.
2. *Variability:* Wide ranges in force measurements indicate significant variations across different meat processing plants and individuals.

5.7 Benefits of Objective Knife Sharpness Assessment

1. *Consistency:* Objective measurements ensure uniform standards across workers, tasks and facilities.

2. *Early Intervention:* Regular, objective assessments throughout the shift can identify dull knives before they significantly impact worker health or productivity, enabling more frequent and timely sharpening interventions.

3. *Data-Driven Improvements:* Objective data allows for targeted interventions and continuous improvement in knife maintenance protocols.

5.8 Broader Implications

1. *Cost Savings:* Reduced MSD risk can lead to fewer worker compensation claims and decreased healthcare costs.

2. *Workforce Stability:* Improved working conditions may result in decreased absenteeism and lower turnover rates.

3. *Quality Improvement:* Sharper knives may lead to more precise cutting, potentially improving product quality.

5.9 Holistic Approach

The findings underscore the need for a comprehensive approach to knife sharpness management in meat processing:

1. Regular, objective knife sharpness assessments conducted at appropriate intervals throughout the shift, not just at the beginning.

2. Implementation of knife sharpness standards.

3. Worker training on proper knife use and maintenance.

4. Ergonomic interventions addressing both tool maintenance and worker technique.

5. Systemic improvements balanced with individual worker considerations.

By addressing knife sharpness as a critical factor in MSD prevention and productivity enhancement, meat processing facilities can significantly improve worker health, safety, and operational efficiency.

6. Conclusion

This white paper has demonstrated the critical impact of knife sharpness on both musculoskeletal disorder (MSD) risk and productivity in the meat processing industry. The evidence presented clearly shows that maintaining consistently sharp knives is not just a matter of efficiency, but a crucial factor in ensuring worker health and safety.

Key takeaways from this research include:

1. **MSD Prevalence**: The alarmingly high rates of MSDs in meat processing, with up to 93.5% of workers experiencing discomfort, underscore the urgency of addressing this issue.
2. **Force Reduction**: Sharp knives can reduce cutting forces by up to 62.8%, significantly decreasing the physical strain on workers and lowering MSD risk.
3. **Ergonomic Improvements**: Sharper knives lead to reduced grip forces, lower cutting moments, and decreased duty cycles, all of which contribute to a more ergonomically sound work environment.
4. **Productivity Gains**: The potential for a 160% increase in task completion over an 8-hour shift highlights the substantial productivity benefits of maintaining sharp knives.
5. **Risk Mitigation**: Analyses using established ergonomic frameworks (MAE, RULA, OCRA) consistently show that increasing knife sharpness can move tasks from high-risk to sustainable work zones.

The findings of this study point to a clear conclusion: objective measurement and management of knife sharpness is not just beneficial, but essential for the meat processing industry. By implementing standardized, objective knife sharpness assessments and maintenance protocols, facilities can:

- Significantly reduce the risk of MSDs among workers
- Enhance productivity and operational efficiency
- Potentially decrease worker compensation claims and associated costs
- Improve overall product quality and consistency

It's clear that knife sharpness should be considered a key performance indicator, on par with other critical metrics of plant efficiency and worker safety. The investment in proper knife maintenance and regular sharpness assessments is likely to yield substantial returns in terms of worker health, productivity, and overall operational excellence.

It is recommended for industry leaders, safety managers, and policymakers to take such actions:

1. Implement objective knife sharpness measurement systems
2. Establish and enforce knife sharpness standards
3. Invest in worker training on proper knife use and maintenance
4. Regularly assess and improve knife sharpening protocols

By prioritizing knife sharpness, the meat processing industry can take a significant step towards creating safer, more efficient workplaces. The evidence is clear: sharper knives lead to healthier workers and more productive facilities.

Bibliography

Arvidsson, I., Balogh, I., Hansson, G.-Å., Ohlsson, K., Åkesson, I., & Nordander, C. (2012). Rationalization in meat cutting – Consequences on physical workload. *Applied Ergonomics*, *43*(6), 1026–1032. https://doi.org/10.1016/j.apergo.2012.03.001

Bevan, S. (2015). Economic impact of musculoskeletal disorders (Msds) on work in Europe. *Best Practice & Research Clinical Rheumatology*, *29*(3), 356–373. https://doi.org/10.1016/j.berh.2015.08.002

Chander, D. S., Tomezzoli, A., Cavatorta, M. P., Gréau, M., Marie, S., & Pontonnier, C. (2024). Biomechanical requirements of meat cutting tasks: A pilot study quantifying tasks sustainability and assistance required at the wrist. *Applied Ergonomics*, *116*, 104186. https://doi.org/10.1016/j.apergo.2023.104186

Claudon, L., & Marsot, J. (2006). Effect of knife sharpness on upper limb biomechanical stresses—A laboratory study. *International Journal of Industrial Ergonomics*, *36*(3), 239–246. https://doi.org/10.1016/j.ergon.2005.11.007

Colombini, D., Occhipinti, E., & Álvarez-Casado , E. (2013). *The revised OCRA Checklist method*. Editorial Factors Human.

Cummings, A. (2015). *HAND, WRIST, FOREARM AND FINGER OCCUPATIONAL INJURIES IN PORK PROCESSING: COMPARISON BY WORK-SITE AND SOURCE OF INJURY* [Undergraduate Student Theses , University of Nebraska-Lincoln]. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1130&context=envstudtheses

Da Costa, B. R., & Vieira, E. R. (2010). Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. *American Journal of Industrial Medicine*, *53*(3), 285–323. https://doi.org/10.1002/ajim.20750

Dempsey, P. G., & McGorry, R. W. (2004). Investigation of a pork shoulder deboning operation. *Journal of Occupational and Environmental Hygiene*, *1*(3), 167–172. https://doi.org/10.1080/15459620490424465

Dos Reis, D. C., Tirloni, A. S., & Moro, A. R. P. (2020). Risk assessment of upper limb musculoskeletal disorders in a poultry slaughterhouse. In P. M. Arezes (Ed.), *Advances in Safety Management and Human Factors* (Vol. 969, pp. 265–272). Springer International Publishing. https://doi.org/10.1007/978-3-030-20497-6_24

Dos Reis, D. C., Tirloni, A. S., Ramos, E., & Moro, A. R. P. (2018). Risk of developing musculoskeletal disorders in a meat processing plant. In R. S. Goonetilleke & W. Karwowski (Eds.), *Advances in Physical Ergonomics and Human Factors* (Vol. 602, pp. 271–278). Springer International Publishing. https://doi.org/10.1007/978-3-319-60825-9_30

Dos Reis, D. C., Tirloni, A. S., Ramos, E., & Moro, A. R. P. (2019). Evaluation of risk factors of upper limb musculoskeletal disorders in a meat processing company. In P. M. F. M. Arezes (Ed.), *Advances in Safety Management and Human Factors* (Vol. 791, pp. 422–430). Springer International Publishing. https://doi.org/10.1007/978-3-319-94589-7_41

Ergonautas. (n.d.). *OCRA Check List*. Ergonautas. Retrieved October 30, 2024, from https://www.ergonautas.upv.es/ergoniza/app_en/land/index.html?method=ocra

Finneran, A., & O'Sullivan, L. (2010). The effects of force and exertion duration on duty cycle time: Implications for productivity. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *20*(4), 324–334. https://doi.org/10.1002/hfm.20224

Gibson, M., & Potvin, J., R. (2016, October). *An equation to calculate the recommended cumulative rest allowance across multiple subtasks*.

Harmse, J., Engelbrecht, J., & Bekker, J. (2016). The impact of physical and ergonomic hazards on poultry abattoir processing workers: A review. *International Journal of Environmental Research and Public Health*, *13*(2), 197. https://doi.org/10.3390/ijerph13020197

ILO. (2015). *GLOBAL TRENDS ON OCCUPATIONAL ACCIDENTS AND DISEASES* [Technical Report]. https://webapps.ilo.org/static/english/osh/en/story_content/external_files/fs_st_1-ILO_5_en.pdf

Juul-Kristensen, B., Fallentin, N., Hansson, G.-Å., Madeleine, P., Andersen, J. H., & Ekdahl, C. (2002). Physical workload during manual and mechanical deboning of poultry. *International Journal of Industrial Ergonomics*, *29*(2), 107–115. https://doi.org/10.1016/S0169-8141(01)00051-8

Karltun, J., Vogel, K., Bergstrand, M., & Eklund, J. (2016). Maintaining knife sharpness in industrial meat cutting: A matter of knife or meat cutter ability. *Applied Ergonomics*, *56*, 92–100. https://doi.org/10.1016/j.apergo.2016.03.010

McCarthy, C. T., Hussey, M., & Gilchrist, M. D. (2007). On the sharpness of straight edge blades in cutting soft solids: Part I – indentation experiments. *Engineering Fracture Mechanics*, *74*(14), 2205–2224. https://doi.org/10.1016/j.engfracmech.2006.10.015

McGorry, R. W., Dowd, P. C., & Dempsey, P. G. (2003). Cutting moments and grip forces in meat cutting operations and the effect of knife sharpness. *Applied Ergonomics*, *34*(4), 375–382. https://doi.org/10.1016/S0003-6870(03)00041-3

McGorry, R. W., Dowd, P. C., & Dempsey, P. G. (2005). A technique for field measurement of knife sharpness. *Applied Ergonomics*, *36*(5), 635–640. https://doi.org/10.1016/j.apergo.2005.04.001

Mohammadi, G. (2012). Risk factors for the prevalence of the upper limb and neck work-related musculoskeletal disorders among poultry slaughter workers. *Journal of Musculoskeletal Research*, *15*(01), 1250005. https://doi.org/10.1142/S0218957712500054

Potvin, J. R. (2012). Predicting maximum acceptable efforts for repetitive tasks: An equation based on duty cycle. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *54*(2), 175–188. https://doi.org/10.1177/0018720811424269

Reis, D. C. D., Ramos, E., Reis, P. F., Hembecker, P. K., Gontijo, L. A., & Moro, A. R. P. (2015). Assessment of risk factors of upper-limb musculoskeletal disorders in poultry slaughterhouse. *Procedia Manufacturing*, *3*, 4309–4314. https://doi.org/10.1016/j.promfg.2015.07.423

Savescu, A., Cuny-Guerrier, A., Wild, P., Reno, G., Aublet-Cuvelier, A., & Claudon, L. (2018). Objective assessment of knife sharpness over a working day cutting meat. *Applied Ergonomics*, *68*, 109–116. https://doi.org/10.1016/j.apergo.2017.11.008

Sompan, R., Keeratisiroj, O., Aungudornpukdee, P., & Mahaboonpeeti, R. (2024). Prevalence of work-related musculoskeletal disorders and ergonomic risk assessment among production workers of pig slaughterhouse in the town municipality of Ang Thong, Thailand. *International Journal of Occupational Safety and Health*, *14*(1), 69–76. https://doi.org/10.3126/ijosh.v14i1.57401

Tirloni, A. S., Dos Reis, D. C., Dos Santos, J. B., Reis, P. F., Barbosa, A., & Moro, A. R. P. (2012). Body discomfort in poultry slaughterhouse workers. *Work*, *41*, 2420–2425. https://doi.org/10.3233/WOR-2012-0651-2420

Tirloni, A. S., Dos Reis, D. C., Ramos, E., & Moro, A. R. P. (2018). Evaluation of bodily discomfort of employees in a slaughterhouse. In R. S. Goonetilleke & W. Karwowski (Eds.), *Advances in Physical Ergonomics and Human Factors* (Vol. 602, pp. 153–162). Springer International Publishing. https://doi.org/10.1007/978-3-319-60825-9_18

Tirloni, A. S., Dos Reis, D. C., Tirloni, S. F., & Moro, A. R. P. (2020). Exertion perception when performing cutting tasks in poultry slaughterhouses: Risk assessment of developing musculoskeletal disorders. *International Journal of Environmental Research and Public Health*, *17*(24), 9534. https://doi.org/10.3390/ijerph17249534

Tirloni, A. S., Reis, D. C. D., Ramos, E., & Moro, A. R. P. (2017). Association of bodily discomfort with occupational risk factors in poultry slaughterhouse workers. *DYNA*, *84*(202), 49–54. https://doi.org/10.15446/dyna.v84n202.62168

Vogel, K., & Eklund, J. (2015). On physiological demands and sustainability in meat cutting. *Ergonomics*, *58*(3), 463–479. https://doi.org/10.1080/00140139.2014.975287