5-2018

# The Impact of UPC Placement on the Biomechanical Injury Risk Factors Associated with Cashier Work

Marcus Payne
*University of Arkansas, Fayetteville*

The Impact of UPC Placement on the Biomechanical Injury
Risk Factors Associated with Cashier Work

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Kinesiology

by

Marcus Payne
University of Arkansas
Bachelor of Science in Kinesiology, 2016

May 2018
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

______________________________
Kaitlin Gallagher, Ph.D.
Thesis Director

______________________________
Michelle Gray, Ph.D.
Committee Member

______________________________
Tyrone Washington, Ph.D.
Committee Member

**Abstract**

The purpose of this study was to investigate the impact of UPC placement on upper-body kinematics and muscle activity associated with cashier work. Seventeen female participants who had worked at least 1000 hours as a cashier and did not meet any exclusion criteria were recruited. Multi-sided UPC items, which included extra and/or larger barcodes, were compared to items with a traditional UPC placement. Two mock carts of eighteen items were scanned for each UPC type. Electromyography was applied bilaterally to the biceps brachii, middle deltoid, flexor digitorum superficialis, and upper trapezius muscles. Cumulative and peak muscle activity were calculated for each trial. Motion capture was placed on the torso, upper arm, forearm, and hand segments and tracked using a Qualysis motion capture system. Range of motion (ROM) values for shoulder flexion/extension, abduction/adduction, and internal/external rotation were calculated. The time to scan each cart from initial movement to return to starting position was also measured. A main effect of UPC type on cumulative muscle activity was found for all muscles (biceps brachii $p$=.002, middle deltoid $p$=.003, flexor digitorum $p$=.001, upper trapezius $p$=.001), all were lower with multi-sided UPC. For peak muscle activity, there was an interaction between UPC type and side ($p$=.036), values on the left were lower with multi-sided UPC items. There was also an interaction between UPC type and side for flexion/extension ROM ($p$=.031), with multi-sided UPC items reducing ROM by an average of 6 degrees. Mock carts with traditional items took an average a 5 fewer seconds to complete. Future studies should investigate if the increased efficiency and lower cumulative muscle activity is beneficial over the course of an entire work shift.

**Acknowledgements**

Funding for this research was provided by the Center for Retailing Excellence. The scanner used for data collection was provided by Digimarc Corporation.

## Table of Contents

## 1. Introduction

Work injuries cost the US economy approximately $110 billion annually, and an estimated $40-50 billion of that is attributed to ergonomic injuries (Occupational Safety and Health Administration [OSHA], 2002), including cashier work. There are several biomechanical risk factors associated with cashier work, including repetitive forces and awkward postures. These factors put cashiers at a high risk of developing upper-limb musculoskeletal injuries (Hagberg *et al*. 1995; Mackay *et al.* 1998). Minimal rest and excessive manual loads may also be contributing to the muscular demands placed on the shoulder during cashier work (Bjelle *et al*. 1979). The result of these issues is a high prevalence of overuse injuries such as carpal tunnel syndrome (Bonfiglioli *et al*. 2007), back pain (Beardmore, 1998), and shoulder discomfort (Sansone, Bonora, Boria, and Meroni, 2014) among cashiers. These risks make it important to investigate ergonomic interventions that will reduce the prevalence of these injuries.

Many issues that burden cashier work are attributed to poor design of the cashier workstation. Because of this, many studies have focused on how the design of the checkout stand can influence upper-body kinematics. Rodacki and Vieira (2010) used a continuous conveyor belt to reduce trunk bending and twisting when reaching for items. They were able to reduce lateral bending, which is a significant factor in developing back pain. Draicchio *et al.* (2012) used a disk wheel in the bagging area to keep workers from having to push items through the bagging area. This resulted in decreased shoulder flexion/extension and horizontal abduction/adduction on both the left and right sides, which puts the cashier at less risk by decreasing muscle activity. These modifications can also help improve efficiency, which may lead to longer rest times for cashier workers. Redesigning cashier stands to be more ergonomically safe is clearly beneficial, but it still leaves the worker repeatedly picking up a large number of items for the duration of long shifts. Studies have shown that handling intermediate to heavy items (1.0 – 5.0 kg) causes the worker to engage the trunk to scan the object (Rodacki *et al*. 2006). This shows that scanning heavier items increases trunk flexion and contributes to the repetitive stress associated with cashier work.

A cashier will spend as much as half of customer transaction time scanning and handling products (Lehman, 1998). Some of this time is spent having to reorient items on the scanner to get them to read properly. Advances have been made in scanner technology to have a second scanning window that can pick up bar-codes more easily. This bi-optic scanner has been shown to reduce muscle activity in the neck and shoulders (Lehman, Psihogios, and Meulenbroek, 2001), which is important because fatigue is less likely to set in and put the cashier at risk for injury. However, the repetitive forces necessary to move items across the scanner, and the lack of appropriate recovery time, still may lead to muscle fatigue and injury. Maciukiewicz *et a*l. (2017) found that the shoulder musculature is the most sensitive to the workloads associated with cashier work. They suggested more recovery breaks to help prevent muscle fatigue.

Universal Product Codes (UPC) were developed in the 1970's and significantly increased labor productivity (Basker 2012). At first, only a single UPC was used to keep cashiers from having to manually enter codes. Modern advancements have led to multiple barcodes being placed on each item with the intent of making them easier to scan. The comparison of traditional and multi-sided UPC in Figure 1 shows how the barcode placement has changed. Instead of one small barcode in the corner, there is a barcode at the top and bottom across the length of the package. The impact of the UPC placement on the aspects of cashier work that put cashiers at risk for injury has not been investigated. It seems possible that increasing the number of barcodes on an item being scanned could prevent the cashier from having to pick up and rotate the item, which contributes to repetitive forces and awkward postures. In combination with a properly designed checkout stand, this could reduce the demands on the shoulders and trunk and decrease the risk for these repetitive use injuries that are prevalent among cashiers.


**Figure 1.** Traditional UPC (left) compared to multi-sided UPC (right)

The purpose of this study is to investigate the impact of UPC placement on upper-body kinematics and muscle activity associated with cashier work. This study will compare traditional UPC placement to a multi-sided UPC placement. The first hypothesis is that both peak muscle activity and cumulative muscle activity, or the total work performed by a single muscle, will be lower for all muscles when using the multi-sided UPC. The second hypothesis is that range of motion will be lower for flexion/extension, abduction/adduction, and internal/external rotation of the shoulder with multi-sided UPC. The third hypothesis is that multi-sided UPC grocery carts will take less time to scan compared to traditional UPC grocery carts.

## 2. Methods

The data used in this study were collected between June and August of 2017. Clearance for the study was obtained through the University of Arkansas Institutional Review Board and all participants provided written consent before the start of the data collection.

### *2.1 Participants*

Seventeen females between the ages of 18 and 65 (age = 30 +/- 12.8 years, height = 1.6 m +/- 0.061 m, mass = 71.1 kg +/- 18.3 kg) who have worked at least 1000 hours as a cashier in the last year were recruited to complete the study. Exclusion criteria included previous shoulder, elbow, wrist, hand, neck or back injury, and having a pacemaker or a cardioverter defibrillator. Participants were recruited from various grocery stores around Fayetteville, Arkansas. Only females were included in the study because cashier workers are predominantly female (Wootton, 1997). Including males may have made it difficult to reach the desired sample size.

### *2.2 Instrumentation*

Participants were instrumented with surface electromyography (EMG) bilaterally on their trapezius, lateral deltoid, biceps brachii, and flexor digitorum superficialis muscles (Table 1) using a Delyss Trigno EMG system (Delsys, Inc., Boston, MA). The specific spots for electrode placement were halfway between the C7 vertebrae and the acromion on the crest of the shoulder for the trapezius, the outermost section of the upper-arm approximately 3cm below the acromion for the deltoid, the largest part of the front of the upper-arm while flexing at the elbow, and three quarters of the way from the wrist to the elbow on the inner arm for the flexor digitorum superficialis. The area was shaved with a disposable razor and cleaned with isopropyl alcohol, then gently abraded to remove any residual oils from the skin. The sensor was then placed on the skin using double-sided tape. Reference contractions were performed so that electromyography data could be normalized. These included holding each arm out to the side at 90 degrees with a 2.5lb weight on the wrist for the trapezius and deltoid, holding the 2.5lb weight in the palm with the elbow bent at 90 degrees for the biceps, and performing a maximal contraction with a hand grip dynamometer for the flexor digitorum superficialis.

**Table 1**. *Description of muscles tested. This information was taken from Criswell & Cram (2011)*

| Muscle | Joint | Action |
|---|---|---|
| Upper Trapezius | Neck/Shoulder | Moving scapula/extending head at the neck |
| Middle Deltoid | Shoulder | Abduction of the arm |
| Flexor Digitorum Superficialis | Wrist | Flexion of the wrist |
| Biceps Brachii | Shoulder/Elbow | Flexion of the elbow |

An 8-camera motion capture system (Qualysis AB, Gotenburg, Sweden) was used to collect kinematic data. Rigid bodies were placed bilaterally on the hand, forearm, and upper-arm, and one on the sternum to track upper extremities and trunk movements. Individual calibration markers were placed bilaterally on the iliac crest, acromion, lateral and medial epicondyles, radial and ulnar styloid processes, and the 2$^{nd}$ and 5$^{th}$ knuckles. A standing trial was recorded with the calibration markers to identify segment lengths and build a skeletal model for each participant.

*2.3 Stand layout*

To simulate a normal checkout stand, a bi-optic scanner was placed on a table that was built up on each side to be flush with the scanning surface (Figure 2). There was no conveyor belt or bagging station, as the study focuses solely on the scanning motion. The scanner height was set at 85 cm.

**Figure 2.** Scanner Table

*2.4 UPC Types*

The two types of UPC tested were traditional and “multi-sided.” Multi-sided items have more barcodes than the traditional placement. The barcodes are typically larger or extended across the length of the item. A couple examples of multi-sided UPC placement are shown below in Figure 3. The traditional items were the same as items used for the multi-sided, but tape was placed over the extra barcodes to match it to a standard UPC placement. The traditional placement is usually two barcodes on a box, and one on a can, jar, or bottle. A full list of items used is detailed in Table 2.


**Figure 3.** Examples of Multi-Sided UPC

**Table 2**. *Description of Products*

| Product Name | Weight (g) | Dimensions (cm) (Height/Width/Depth) or (Height/Diameter) |
|---|---|---|
| Corn Squares Cereal | 396 | 29x20x7 |
| Fruit & Grain Cereal Bars | 295 | 15x20x4 |
| Instant Oatmeal | 382 | 20x13x8 |
| Elevation Treat Bar | 170 | 14x14x4 |
| Breakfast Biscuits | 250 | 13x16x6 |
| Tri-colored Rotini | 453 | 19x13x5 |
| Original Saltine Crackers | 454 | 11x24x11 |
| Beauty Bar Soap | 227 | 7x11x7 |
| Crushed Tomatoes Can | 794 | 12x11 |
| Pear Slices Can | 432 | 11x8 |
| Roasted Red Pepper Dressing | 340 | 20x6 |
| Kansas City BBQ Sauce | 538 | 18x7 |
| Mango Peach Salsa | 454 | 11x8 |
| Canola Oil | 1361 | 28x10x8 |
| Organic Lemonade | 1814 | 27x11x9 |
| Mandarin Oranges Fruit Cups | 452 | 10x17x8 |
| Boulder Napkins | 435 | 15x30x11 |
| White Rounds Tortilla Chips | 369 | 34x22x8 |

*2.5 Experimental Protocol*

Participants arrived at the lab and completed informed consent and medical screening forms, then had their anthropometric measures taken. They were familiarized with the scanner and the types of UPC being tested. They were then instrumented with the EMG sensors reference contractions were recorded. Motion capture rigid bodies were applied and a standing trial with the calibration markers was recorded to build a participant-specific model. They completed carts of traditional UPC and multi-sided UPC items in a randomized order. For each cart, they completed one practice trial and then two trials were recorded. They were asked to start with their hands placed flat on the table in front of them and to scan items as they normally would while working and then to return to the starting position once they were finished. They were also instructed to scan as if someone was bagging for them, so they only had to set the items down after they were scanned. There was a person on each end of the table pushing items to the scanner and removing them after they were scanned. When items were placed on the scanning table, they were placed in a random order and a random orientation to simulate how items are usually arbitrarily placed on a conveyor belt.

*2.6 Data Analysis*

Electromyography data was processed according to standard protocols in Visual3D (C-Motion, Germantown, MD). The mean was subtracted from the signal, full wave rectified, and filtered using a Butterworth filter with a cutoff of 4 Hz. Three-dimensional angles were calculated in Visual3D. Time taken to scan carts was calculated by using events to mark when each hand begins to move and returns to starting position. This was done using the electromyography data of the biceps and deltoid.

*2.7 Outcome Measures*

For all variables, the mean of the two trials used was taken as the outcome measure for that trial.

**Electromyography.** Cumulative muscle activity was calculated using integrated EMG. This estimates the total amount of muscle activity used during a trial by calculating the area under the curve of the EMG signal. Peak muscle activity was also extracted. All muscle activity was normalized using reference contractions.

**Kinematics.** The rigid bodies were tracked and used to measure angles of shoulder flexion/extension, abduction/adduction, and internal/external rotation. An amplitude probability function (APDF) will be used to calculate the median angle and range between the $10^{th}$ and $90^{th}$ percentiles.

*2.8 Statistical Analysis*

*H1: Cumulative muscle activity and peak muscle activity will be lower for all muscles with multi-sided UPC compared to traditional UPC.*

To test the first hypothesis, a two-way ANOVA with factors of UPC type (traditional versus multi-sided) and arm (left or right) was run on both the cumulative muscle activity and the peak muscle activity. Tukey post hoc tests were performed on significant main effects.

*H2: Range of motion of shoulder flexion/extension, abduction/adduction, and internal/external rotation will be less with multi-sided UPC.*

To test this hypothesis, a two-way ANOVA was run on ROM values of shoulder flexion/extension, abduction/adduction, and internal/external rotation. Tukey post hoc tests were performed on significant main effects.

*H3: Multi-sided UPC carts will take less time to complete compared to traditional UPC.*

To test the third hypothesis, a paired t-test was run on the average time it took for participants to scan the multi-sided versus traditional UPC grocery carts.

*2.9 Assumptions and Limitations*

It was assumed that the participants followed instructions and scanned items the same way that they would while working. It is also assumed that the calibration of our motion capture system was accurate. This study is limited in that only two trials of each cart were completed, so it does not take into account how the repetitive nature of cashier work might lead to fatigue and changes of the scanning motion over the course of a work shift.

## 3. Results

The data for one participant was excluded due to issues with the EMG data during collection. For a second participant, the right middle deltoid EMG had abnormal spikes, so that sensor was also excluded from the analysis.

### *3.1 Cumulative Muscle Activity*

A full statistics summary is detailed in Table 3. There was a main effect of UPC type on cumulative muscle activity for the biceps brachii ($p$=0.0022), middle deltoid ($p$=0.0030), flexor digitorum superficialis ($p$=0.0010), and upper trapezius ($p$=0.0005) muscles. For all muscles, the cumulative activity was lower with the multi-sided UPC (Figure 4). There was also a main effect of side on the upper trapezius ($p$=0.0281), with total muscle activity being lower on the left side (355.7(+/-153.5)% RC*s) compared to the right side (451.6(+/-275.8)% RC*s).

**Table 3.** *Summary of ANOVA results for integrated EMG activity.*

| **Integrated EMG** | Biceps Brachii | Middle Deltoid | Flexor Digitorum | Upper Trapezius |
|---|---|---|---|---|
| Side | p=.260 | p=.056 | p=.932 | **p=.028** |
| UPC | **p=.002** | **p=.003** | **p=.001** | **p=.001** |
| Side*UPC | p=.783 | p=.050 | p=.075 | p=.165 |

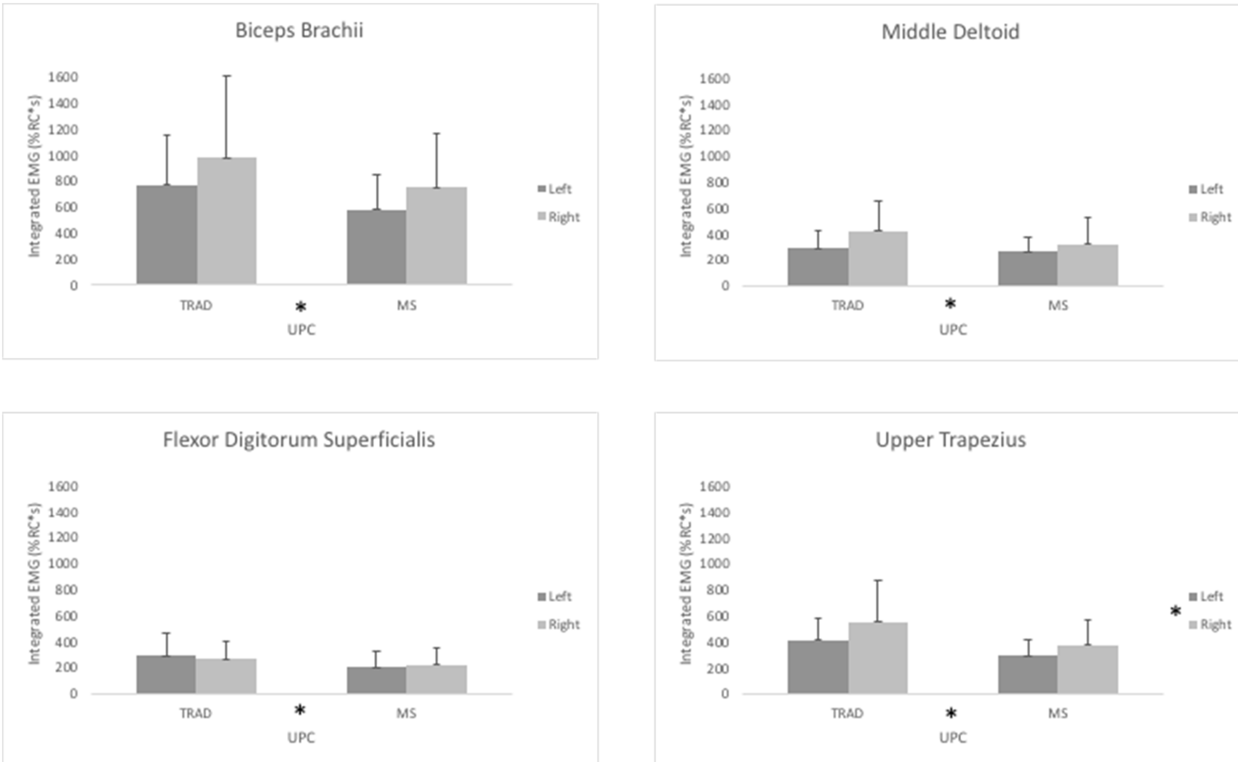


**Figure 4.** Average integrated EMG values (with standard deviation bars) for each muscle in terms of percent reference contraction (%RC*s). Significant differences are denoted by an asterisk.

*3.2 Peak Muscle Activity*

A full summary of results can be found in Table 4. There was a main effect of side on peak EMG found for the upper trapezius ($p$=0.005) and middle deltoid ($p$=0.013), with peak values on the right being higher (110.3(+/-50.7)%RC and 76.7(+/-34.3)%RC, respectively) compared to the left side (70.1(+/-27.5)%RC and 50.3(+/-16.2)%RC, respectively).

An interaction between UPC type and side was found for the flexor digitorum superficialis muscle ($p$=0.036). A post-hoc test found that there was a significant difference between UPC types on the left side ($p$=0.001). Peak EMG values on the left side were higher with the traditional UPC (69.3(+/-42.9)%RC ) than with the multi-sided UPC 51.5(+/-30.1)%RC).

**Table 4.** *Summary of ANOVA results for peak EMG activity*

| **Peak EMG** | Biceps Brachii | Middle Deltoid | Flexor Digitorum | Upper Trapezius |
|---|---|---|---|---|
| Side | p=.052 | **p=.013** | p=.123 | **p=.005** |
| UPC | p=.346 | p=.324 | p=.009 | p=.176 |
| Side*UPC | p=.227 | p=.079 | **p=.036** | p=.600 |

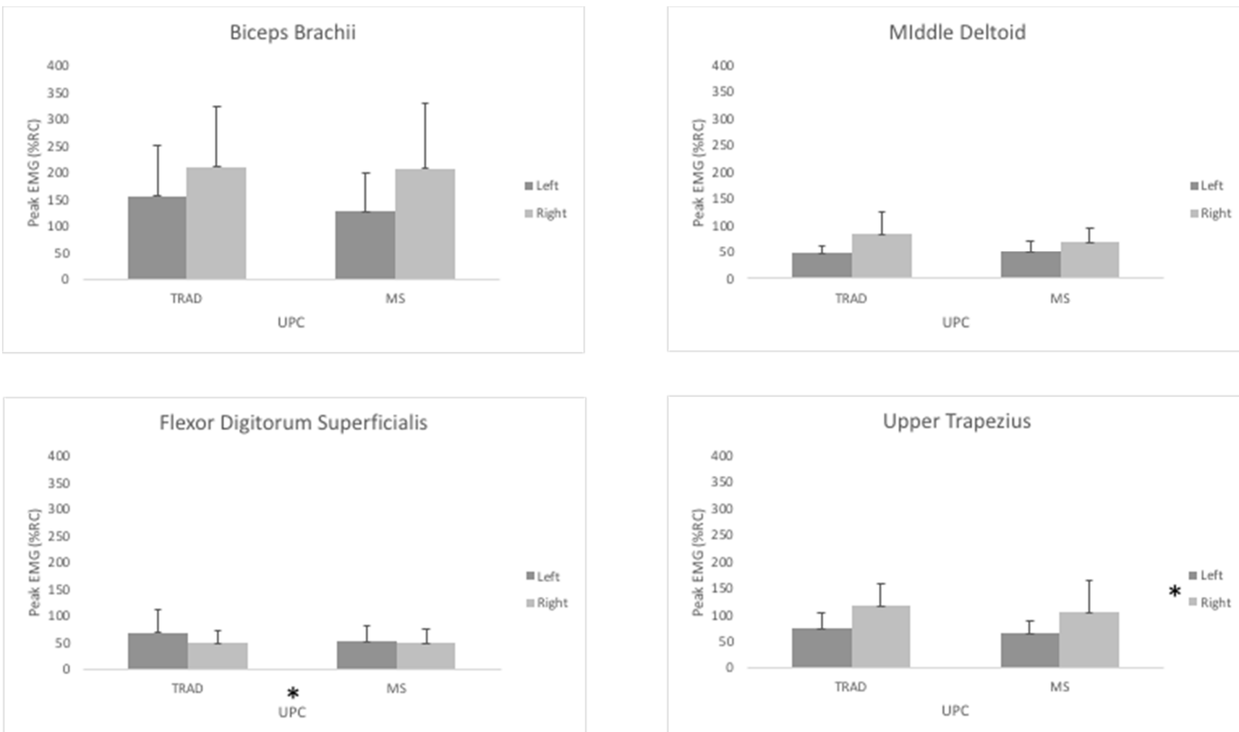


**Figure 5.** Average peak EMG values (with standard deviation bars) for each muscle in terms of percent reference contraction (%RC). Significant differences are denoted by an asterisk.

*3.3 Shoulder Range of Motion*

A full summary of the ANOVA results is detailed below in Table 5. A main effect of side was found on shoulder range of motion in abduction/adduction ($p$<.001). Average ROM was 14.3 (+/-5.9) degrees on the left side compared to 23.1 (+/-7.4) degrees on the right side. There was also an interaction between UPC type and side in the flexion/extension direction ($p$=0.031). A post-hoc test on the interaction found that there was a significant difference between UPC types on the right side ($p$=0.035). The average range of motion for flexion/extension on the right side was higher when using the traditional UPC (36.3(+/-15.3)) compared to the multi-sided UPC (30.6(+/-5.4) degrees).

**Table 5.** *Summary of ANOVA results for shoulder range of motion.*

| **Range of Motion** | Flexion/ Extension | Abduction/ Adduction | Internal/ External Rotation |
|---|---|---|---|
| Side | p<.001 | **p<.001** | p=.186 |
| UPC | p=.140 | p=.064 | p=.115 |
| Side*UPC | **p=.031** | p=.305 | p=.592 |

*3.4 Scanning Time*

There was a significant difference in the time taken to scan a complete cart of traditional UPC items compared to multi-sided UPC items ($p$=0.001). It took an average time of 24.9 (+/-6.0) seconds to complete a traditional cart compared to 20.1 (+/-4.8) seconds for a multi-sided cart.

## 4. Discussion

The purpose of this study was to investigate what impact UPC placement has on upper-body kinematics and the muscle activity associated with cashier work. Our first hypothesis that cumulative muscle activity and peak muscle activity would be lower for all muscles with multi-sided UPC items compared to traditional UPC was partially supported. Cumulative muscle activity was lower for all muscles, but peak activity was only reduced for the flexor digitorum superficialis. Our second hypothesis, that shoulder range of motion would be lower in all directions with multi-sided UPC items, was also partially supported. Flexion/extension range of motion was lower with the multi-sided UPC items, specifically on the right side. Our third hypothesis that it would take less time to scan multi-sided item carts was supported. The time to scan a mock cart was reduced by an average of 5 seconds with the multi-sided UPC items.

The multi-sided UPC was able to reduce cumulative muscle activity for one mock grocery cart more than it reduced peak muscle activity. Cumulative EMG was significantly lower for all muscles with the multi-sided UPC, while only the flexor digitorum superficialis was lower for peak EMG. Our measure of integrated EMG looks at the total amount of activity for a particular muscle for the duration of one trial (or cart). This means that the multi-sided UPC item carts that took less time to scan should have less cumulative activity, but it is difficult to assess how the increased number of carts that can be scanned during one shift will impact this. Peak EMG extracts the highest value (in percent reference contraction) recorded during the trial, so it is a measure of the hardest a muscle had to work while completing a cart. High levels of peak EMG could put a cashier at risk for acute injuries, while higher levels of cumulative muscle activity would be more associated with chronic injuries.

Shoulder range of motion was only impacted by UPC type in the flexion/extension direction. Flexion/extension was significantly lower on the right side with multi-sided UPC compared to traditional UPC. The right hand was being used to pick up items, so a lower range of motion indicates that items were not being lifted as high as the cashier picked them up to be scanned. Even though the difference was only about 6 degrees, this small change could have a large impact over time.

Participants were scanning from right to left, and several differences were found between the right and left sides. Both cumulative and peak EMG were lower on the left side compared to the right for the upper trapezius, and peak EMG was lower on the left side for the middle deltoid independent of UPC type. The right arm was used to reach over and pick up items, engaging the upper trapezius and the middle deltoid and leading to more activity for those muscles on the right side. Lastly, the flexor digitorum superficialis was significantly higher on the left side with traditional UPC items compared to multi-sided UPC items. The left flexor digitorum superficialis may be engaged when the cashier grips and rotates an item to find the barcode. There was also a difference between the left and right side for abduction/adduction, with the right side showing an increased range of motion. When scanning an item, the participant reached (shoulder abduction) to the right to pick up items and performed adduction across their body to scan the item. After the items were scanned, participants were instructed only to set them to the left of the scanner as if they had a bagger, therefore, there was not as much of a role of for the left side in this simulation.

The time it took to scan the mock grocery cart was lowered by an average of 5 seconds with the multi-sided UPC items. This increased efficiency could result in workers having more time to rest in between carts, or it could mean that more items are scanned in the same amount of time.

The lower values of cumulative muscle activity are directly impacted by this increase in efficiency. If the cashier is scanning carts for an entire shift, it may result in the similar cumulative muscle as with traditional UPC for an entire day, just with a higher number of carts scanned. This may be beneficial to the business because it increases efficiency, but it does not reduce the risk of injury for the worker.

A limitation of our study is that we did not account for the height of the cashier. The workstation was set at a specific height (85 cm), so short cashiers would need to flex at the shoulder more than taller cashiers. This could result in increased shoulder muscle activity and an increased risk for injury. Conversely, tall cashiers may have to flex at the trunk more, putting them at an increased risk to develop back pain. These issues can be taken into account by considering the design of the cashier workstation; however, in a typical workplace, the cashier stands are not height adjustable. To address this, future work should collect cashiers of a wide range of heights to determine if this plays a role in altering muscle activity and kinematics. A second limitation is that each participant completed a total of only four carts. We are unable to assess what impact fatigue from multiple hours of scanning might have on muscle activity. Lastly, this study considered only the scanning motion of the checkout process. Many cashier workers are also responsible for bagging items after they are scanned. Including the bagging process may impact upper-body kinematics as the cashier has to bend, twist, or reach to bag items; however, it was not a point of emphasis in this study because this would occur regardless of the UPC type used by the store.

While multi-sided UPC was able to reduce cumulative muscle activity in a controlled setting, other factors will also impact risk of injury and need to be considered. Training protocols are important as interventions such as redesigned workstations, and new UPC technology are implemented into the workplace. These advancements can be beneficial but will require proper instructions on how to efficiently and safely use them. For example, long-time cashiers may be so accustomed to picking out certain items to scan and searching for a barcode that they may not adjust to new barcode technology without training.

Finally, self-checkout stands are becoming more and more common in stores. Consumers will likely have little to no knowledge of UPC technology, so it will be important that these features are communicated to them. Without proper understanding, they will not be able to take advantage of the increased efficiency and decreased risk associated with these advances.

## 5. Conclusions

Cashier workers are at an increased risk of developing musculoskeletal injuries due to the repetitiveness and awkward postures associated with scanning items. Multi-sided UPC items could be useful in limiting some of these risk factors. Multi-sided UPC items were able to reduce cumulative activity for all muscles that were looked at and peak activity for the forearm, as well as reducing shoulder flexion and the time taken to complete the cart. The data from this study indicate that the multi-sided UPC can increase scanning efficiency compared to traditional UPC, but how this increased efficiency will impact the worker over an entire shift remains unclear. Further studies are needed to assess if these changes are beneficial through the duration of a workday and over time. It is possible that these changes, although slight, could reduce the risk of injury to a person who works as a cashier. Future studies can investigate how combining workstation interventions with UPC interventions can reduce these risk factors.

## 6. References

Baron, S. L., & Habes, D. (1992). Occupational musculoskeletal disorders among supermarket cashiers. *Scandinavian journal of work, environment & health*, 127-129.

Basker, E. (2012). Raising the barcode scanner: Technology and productivity in the retail sector. *American Economic Journal: Applied Economics*, *4*(3), 1-27.

Beardmore, D., 1998. The identification and control of musculoskeletal risks to supermarket checkout workers. M.Sc. Dissertation, University of Salford, Manchster, England.

Bjelle, A., Hagberg, M., & Michaelsson, G. (1979). Clinical and ergonomic factors in prolonged shoulder pain among industrial workers. *Scandinavian journal of work, environment & health*, 205-210.

Bonfiglioli, R., Mattioli, S., Fiorentini, C., Graziosi, F., Curti, S., & Violante, F. S. (2007). Relationship between repetitive work and the prevalence of carpal tunnel syndrome in part-time and full-time female supermarket cashiers: a quasi-experimental study. *International archives of occupational and environmental health*, *80*(3), 248-253.

Criswell, E., & Cram, J. R. (2011). *Cram's introduction to surface electromyography*. Sudbury, MA: Jones and Bartlett.

Draicchio, F., Trebbi, M., Mari, S., Forzano, F., Serrao, M., Sicklinger, A., Ranavolo, A. (2012). Biomechanical evaluation of supermarket cashiers before and after a redesign of the checkout counter. *Ergonomics*, *55*(6), 650-669.

Hagberg M., Silverstein B., Wells R., Smith M.J., Hendrick H.W., Carayon P., Perusse M. (1995) In: Kurorinka *, Forcier I. (eds) Work related musculoskeletal disorders (WMSDs): a reference book of prevention. Taylor & Francis, London, pp 17-138.

Lehman, K. R. (1998). *Performance analysis at a Dutch retailer*. Internal Report (Atlanta: NCR Corporation).

Lehman, K. R., Psihogios, J. P., & Meulenbroek, R. G. (2001). Effects of sitting versus standing and scanner type on cashiers. *Ergonomics*, *44*(7), 719-738.

Mackay, C., Burton, K., Boocock, M., Tillotson, M., & Dickinson, C. (1998). *Musculoskeletal disorders in supermarket cashiers*. (Sudbury: HSE Books.

Maciukiewicz, J. M., Lang, A. E., Vidt, M. E., Grenier, S. G., & Dickerson, C. R. (2017). Characterization of cashier shoulder and low back muscle demands. *International Journal of Industrial Ergonomics*, *59*, 80-91.

Occupational Safety and Health Administration. The New OSHA: Reinventing Worker Safety and Health [Web Page]. May 8, 2002. *Available at: www. osha. gov/oshinfo/reinvent. html*.

Rodacki, A. L. F., & Vieira, J. E. (2010). The effect of different supermarket checkout workstations on trunk kinematics of checkout operators. *Brazilian Journal of Physical Therapy, 14*(1), 38-44.

Rodacki, A. L. F., Vieira, J. E. A., Okimoto, M. L. L. R., Fowler, N. E., & Rodacki, C. d. L. N. (2006). The effect of handling products of different weights on trunk kinematics of supermarket cashiers. *International Journal of Industrial Ergonomics. Feb2006, 36*(2), 129.

Sansone, V., Bonora, C., Boria, P., & Meroni, R. (2014). Women performing repetitive work: Is there a difference in the prevalence of shoulder pain and pathology in supermarket cashiers compared to the general female population?. *International journal of occupational medicine and environmental health*, *27*(5), 722-735.

Wickham, J., Pizzari, T., Stansfeld, K., Burnside, A., & Watson, L. (2010). Quantifying 'normal'shoulder muscle activity during abduction. *Journal of Electromyography and Kinesiology*, *20*(2), 212-222.

Wootton, B. H. (1997). Gender differences in occupational employment. *Monthly Lab. Rev.*, *120*, 15.

# 7. Appendix

UNIVERSITY OF ARKANSAS

Office of Research Compliance
Institutional Review Board

July 27, 2017

MEMORANDUM

| | |
|---|---|
| TO: | Molly Jensen, Kaitlin Gallagher, Anna Simmons, Mariam Bartlett, Raymond Towne, Marcus Payne, Katie Glover |
| FROM: | Ro Windwalker<br>IRB Coordinator |
| RE: | PROJECT MODIFICATION |
| IRB Protocol #: | 16-09-101 |
| Protocol Title: | *Advances in UPC Technology: Might Watermarking the Barcode Reduce the Potential for Cashier Ergonomic Injuries* |
| Review Type: | ☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB |
| Approved Project Period: | Start Date: 07/22/2017 Expiration Date: 04/27/2018 |

Your request to modify the referenced protocol has been approved by the IRB. **This protocol is currently approved for 75 total participants.** If you wish to make any further modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

Please note that this approval does not extend the Approved Project Period. Should you wish to extend your project beyond the current expiration date, you must submit a request for continuation using the UAF IRB form "Continuing Review for IRB Approved Projects." The request should be sent to the IRB Coordinator, 109 MLKG Building.

For protocols requiring FULL IRB review, please submit your request at least one month prior to the current expiration date. (High-risk protocols may require even more time for approval.) For protocols requiring an EXPEDITED or EXEMPT review, submit your request at least two weeks prior to the current expiration date. Failure to obtain approval for a continuation *on or prior to* the currently approved expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu.

109 MLKG • 1 University of Arkansas • Fayetteville, AR 72701-1201 • (479) 575-2208 • Fax (479) 575-6527 • Email irb@uark.edu

**ADVANCES IN UPC TECHNOLOGY: MIGHT WATERMARKING THE BARCODE REDUCE THE POTENTIAL FOR CASHIER ERGONOMIC INJURIES?**

**Consent to Participate in a Research Study**

Principal Researchers: Molly R. Jensen PhD, Walton College of Business;
Kaitlin Gallagher PhD, Health, Human Performance and Recreation

**INVITATION TO PARTICIPATE**

You are invited to participate in a research study about cashier hand, wrist, arm and upper body movements. You are being asked to participate in this study because you are an experienced cashier.

**WHAT YOU SHOULD KNOW ABOUT THE RESEARCH STUDY**

*Who are the Principal Researchers?*

Molly R. Jensen, Associate Professor for Marketing
Walton College of Business
mjensen@uark.edu
479-575-5503

Kaitlin Gallagher, Assistant Professor for Exercise Science
College of Education and Health Professionals
kmg014@uark.edu
479-575-5173

*What is the purpose of this research study?*
The purpose of this study is to explore new technologies in the area of consumer goods packaging. Universal Product Codes (UPC) are changing and with this study we would like to see if these changes have any impact upon your potential exposure to situations that might cause ergonomic injuries as you scan products.

*Who will participate in this study?*
Experienced Cashiers between the ages of 18-60. This is defined as working as a cashier for at least 1000 hours in the last year. You will not be able to participate if you

(1) have a previous shoulder, elbow, wrist, hand, neck or back injury, or
(2) have a pacemaker.
(3) have a cardioverter defibrillator

*What am I being asked to do?*
You will be asked to come to the Exercise Science Research Center, located on the 3rd floor of the HPER Building at 155 Stadium Drive, Fayetteville, Arkansas.

Your participation will require the following:

> You will be asked to fill out a medical screening form prior to participating. This ensures that you do not have any of the exclusion criteria mentioned above. You will not be able to participate in the study if you have any of exclusion criteria mentioned in the previous section.
>
> You will be required to wear a sleeveless shirt. A gender-matched experimenter will be responsible for placing the sensors.

IRB #16-09-101
Approved: 07/22/2017
Expires: 04/27/2018

Sensors will be placed on your hands, arms, head, and upper back using double-sided tape. These sensors are used to track your posture during the mock scanning.

Electrodes will be used to track muscle activity of your upper body. The locations will be your left and right shoulder, upper back, and neck. This technology is similar to what is used to measure the electrical activity of your heart. The area where the electrodes will be placed will be lightly shaven to remove dead skin cells and then cleaned with rubbing alcohol. The electrodes will then be placed on the skin.

In order to understand how hard your muscle can contract, we need to have your perform a contraction of each muscle as hard as you can. You will be instructed by the experimenter to contract as hard as possible for 5 seconds and then given a chance to rest for two minutes. You will do this a maximum of three times for each muscle (18 contractions in total).

You will be scanning products using a traditional conveyor belt and flat scanner while we measure your hand, wrist, arm and upper body movements and muscle activity. You will receive time to get used to the different scanning techniques. After that, you will scan different items individually (up to 48 scans in total) and then perform a mock grocery scan six times.

*What are the possible risks or discomforts?*

**Awkward postures:** Participants may need to assume awkward postures to properly scan certain grocery items. These postures are not above what a typical cashier would see in their typical workday.

**Skin redness:** Some people experience minor skin redness due to the double-sided tape. This redness usually dissipates after 24-48 hours.

*What are the possible benefits of this study?*

We are exploring the potential use of UPC scanning technology that has less potential for ergonomic injuries to cashiers than traditional scanning technology.

*How long will the study last?*
It is estimated that you will take about three hours to complete the study from start to finish.

*Will I receive compensation for my time and inconvenience if I choose to participate in this study?*
You will be paid $100 for your time and have your parking on the University of Arkansas campus compensated.

*Will I have to pay for anything?*
No, there is no cost to you for participation.

*What are the options if I do not want to be in the study?*
If you do not want to be in this study, you may refuse to participate. Also, you may refuse to participate at any time during the study. Your preexisting relationship with the University, if any, will not be affected in any way if you refuse to participate.

*How will my confidentiality be protected?*
All information will be kept confidential to the extent allowed by applicable State and Federal law and University policy. All information collected will be associated with a random code provided to you at the start of the session. There will be no connection kept between your signed consent form and the information collected during the study.

IRB #16-09-101
Approved: 07/22/2017
Expires: 04/27/2018

*Will I know the results of the study?*
At the conclusion of the study you will have the right to request feedback about the results. You may contact the Principal Researcher, Molly R Jensen PhD 479-575-5503 or mjensen@uark.edu OR Kaitlin Gallagher (479-466-7187, kmg014@uark.edu). You will receive a copy of this form for your files.

*What do I do if I have questions about the research study?*
You have the right to contact the Principal Researcher listed below for any concerns that you may have.

Molly R Jensen PhD
mjensen@uark.edu
479-575-5503
OR
Kaitlin Gallagher PhD
479-575-5173
kmg014@uark.edu

You may also contact the University of Arkansas Research Compliance office listed below if you have questions about your rights as a participant, or to discuss any concerns about, or problems with the research.

Ro Windwalker, CIP
Institutional Review Board Coordinator
Research Compliance
University of Arkansas
109 MLKG Building
Fayetteville, AR  72701-1201
479-575-2208
irb@uark.edu

I have read the above statement and have been able to ask questions and express concerns, which have been satisfactorily responded to by the investigator. I understand the purpose of the study as well as the potential benefits and risks that are involved. I understand that participation is voluntary. I understand that significant new findings developed during this research will be shared with the participant. I understand that no rights have been waived by signing the consent form. I have been given a copy of the consent form.

Print Name_________________________________________

Sign Name_________________________________________

Date          _________________________________________

IRB #16-09-101
Approved: 07/22/2017
Expires: 04/27/2018

**MEDICAL SCREENING FORM**

*Advances in UPC technology: Might watermarking the barcode reduce the potential for cashier ergonomic injuries?*

Participant Code:_____________

Inclusion criteria:

1. Between the ages of 18-60
2. Previous experience as a grocery cashier – worked at least 1000 hours over the past year in a cashier position.

Exclusion criteria:

1. Previous upper extremity, (shoulder, elbow, wrist, hand), neck, or back surgery.
2. Have a pacemaker – inertial motion sensors have signals that may interfere with a pacemaker
3. Have a cardioverter defibrillator

<u>Medical History</u>

Have you had an injury to or surgery on the following body locations? If yes, please elaborate:

| **Region** | **Yes/No** | **Date** | **Additional Details** |
|---|---|---|---|
| Head | | | |
| Neck | | | |
| Shoulder/upper arm | | | |
| Elbow/forearm | | | |
| Wrist/Hand | | | |
| Low back | | | |

Do you currently have a pacemaker or cardioverer defibrillator? YES NO Please circle

Have you had a pacemaker or cardioverter defibrillator in the past? YES NO Please circle

Recruitment Script – will provided verbally, through email, and an advertisement on the Exercise Science Research Center website and Newswire

Subject Headline: Participants needed for a research study looking at how cashiers scan types of products.

Many cashiers have very specific ways to do their job. We are interested in how you scan items using a barcode scanner. In this study we have some products with a new type of UPC code. We are interested to see if this new type of UPC changes the way you scan product, if you use different arm movements and if you scan faster or slower.

We are looking for female participants 18 years of age or older participate in a study who have worked as a cashier for at least 1000 hours in the last two years. So if you worked anywhere between 20 and 40 hours a week for the past year, you are eligible to participate.

You should not volunteer for this study if you are under the age of 18, have previous shoulder, elbow, wrist, hand, neck, or back injury surgery. Also, due to some of the equipment we will use, you should not volunteer if you have a pacemaker or a cardioverter defibrillator.

You will come to the Biomechanics Laboratory at the University of Arkansas HPER Building for one 2-hour session. During this study, your arm muscle activation and posture monitored while scanning groceries through a simulated cashier station.

We do not know if you will get any benefits by taking part in this study. This research might help us learn more about possible risk factors for upper extremity injuries while scanning product. There may be no personal benefit from your participation but the information gained by doing this research may help others in the future. Participants will be compensated $100 for their time and we will cover the cost of parking on campus.

If you are interested in participating or have any additional questions, please contact Kaitlin Gallagher at kmg014@uark.edu or Molly Jensen at mjensen@uark.edu. This study has been approved by the University Institutional Review Board.

# PHOTO/VIDEO IMAGE RELEASE FORM

Date: _______________

I hereby grant the University of Arkansas permission to interview me and/or use my likeness in photograph(s)/video in any and all of its publications and in any and all other media, whether now known or hereafter existing, controlled by the University of Arkansas, in perpetuity, and for other use by the University.

All negatives, positives, digital files, together with the prints, are the property of the University of Arkansas.

The University of Arkansas reserves the right to use these photographs and/or video in perpetuity in any media whether now known or hereafter existing.

I will make no monetary or other claim against the University of Arkansas for the use of the interview and/or the photograph(s)/video.

I understand that I am waiving any Family Educational Rights and Privacy Act (FERPA) related holds pertaining to the images gathered for this session.

I hereby acknowledge that I am 18 years of age or older and have read and understood the terms of this release. I can also sign this release form granting the same authorization for use and reproduction of images of my child (named below) who is under 18.

Name: ________________________________________________________________________
signature printed name

Child's name (if under 18)_______________________________________________________________

_________________________________________________________________________
e-mail address phone number

COLLEGE OF EDUCATION AND HEALTH PROFESSIONS • UNIVERSITY OF ARKANSAS
Heidi Wells, director of communications
479-575-3138, stambuck@uark.edu