Fatigue among restaurant workers

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Fatigue Among Restaurant Workers

by

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This work is dedicated to my loving and supportive family.

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ABSTRACT

The restaurant industry consists of a large and diverse workforce. Despite a large proportion of the population working in this industry that has an elevated risk for injury, there is not a lot of existing research on existing risk factors, especially fatigue. There is little evidence known on the manifestation of fatigue in restaurant workers, and if any differences between job roles are present.

Physical activity data from two inertial measurement units (IMUs) (GT9X Link, Actigraph LLC., Pensacola, FL) and self-reported measurements of fatigue are used to estimate the effect of job role on fatigue across a work shift. Thirteen workers (servers and cooks) were observed during three consecutive work shifts at a small restaurant. Physical activity (raw accelerations) of the wrist and hip were collected for each job role. Accelerations were then categorized into levels of physical activity (light, moderate, vigorous) using energy expenditure units (MET-seconds) and then placed into percent time spent in those categories. Self-reported factors using the Swedish Occupational Fatigue Inventory (SOFI) were collected before, during, and after each shift. Servers' responses during a shift were collected every hour. Cooks' responses during a shift were only calculated once in the middle of the shift. SOFI scores were then calculated by job role. Effects of physical activity on SOFI scores were also examined.

Job role was not related to any of the self-reported fatigue factors. However, self-reported fatigue did significantly increase throughout a shift for all self-reported fatigue factors for both job roles. Average shift lengths were observed to be relatively the same, but cooks had an overall higher measure of total physical activity (MET-sec) for both the hip and wrist sensors when compared to the servers. Also, job role did significantly affect percent time spent in all levels of wrist activity and vigorous hip activity. Cooks spent over 13.2% of their time in vigorous wrist

activity which was almost two times higher than the 7.9% of time for servers. When measuring hip activity, servers spent 10.8% of time vigorous activity, doubling the cooks' 4.9% of time spent in this category. Significant interactions between job role and time since the start of the shift were observed among sleepiness, physical exertion, and lack of motivation.

Many variables contribute to ratings of fatigue; however, using physical activity and fatigue-related questionnaires are helpful in the estimation of fatigue. Understanding fatigue and its occurrence among restaurant workers will further existing knowledge about fatigue and hopefully aide in the management of restaurant operations and increase employee well-being.

PUBLIC ABSTRACT

The restaurant industry is a popular occupation that also consists of elevated rates for injury. For fatigue, many existing studies use only a self-reported metric, while few use an objective measure. However, using both metrics at the same time to study fatigue risk factors can provide a more accurate estimation of fatigue during a shift, especially when it comes to different job roles.

The aim of this study was to estimate the effect of job role on self-reported fatigue along with the effect of job role and time on physical activity and self-reported fatigue. Physical activity data and self-reported measurements of fatigue were collected for three work shifts among 13 workers (8 servers and 5 cooks). Inertial sensors (i.e., accelerometers and gyroscopes) were worn on the dominant wrist and the non-dominant hip to capture continuous physical activity data, while a fatigue questionnaire was completed before, during, and after work to capture self-reported feelings of fatigue. Analyses examined the effects job role (server vs. cook), time since the start of a shift, and their interaction on measures of both physical activity levels and self-reported fatigue. While the main effect of job role was not statistically significant for most measures, the main effect of time and the interaction between job role and time was statistically significant; in general, cooks experienced fatigue at a faster rate than servers.

Even though there are multiple variables for fatigue, the measurement of physical activity and the use of questionnaires can be used to estimate risk factors for fatigue and their effects on restaurant workers. Understanding fatigue in different job roles can help with managerial tasks pertaining to restaurant operations and increase employee well-being.

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CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1. Restaurant Statistics

In 2020, an estimated 12.5 million people were employed in full-service restaurants (NAICS code: 722511) (National Restaurant Association, 2021; U.S. Census Bureau, 2017). In full-service restaurants, there were 91,800 nonfatal occupational injuries and illnesses with an incidence rate (IR) of 2.7 cases per year per 100 full-time equivalent (FTE) workers (BLS, 2020a). The IR for full-service restaurants was similar to the "all private industry" IR of 2.8 per 100 FTE. Similarly, 24,980 injuries/illnesses involving days away from work (DAFW) occurred in full-service restaurants with an IR of 88.3 per 10,000 FTE, while the IR for injuries/illnesses involving DAFW for all private industry was 86.9 per 10,000 FTE (BLS, 2020a). Thus, a cursory examination of recent industry-level surveillance data does not immediately suggest workers in full-service restaurants to be a high-risk occupational group.

Job roles within full-service restaurants can be generally categorized as "front of house" or "back of house." Front of house job roles include bartenders, waiters and waitresses, hosts and hostesses, assistants, and managerial staff. Back of house job roles include chefs and head cooks, cooks, food preparation workers, and dishwashers. Each job role can have a different injury and illness incidence rate, along with different mechanisms of those injuries and illnesses. The total IR among food preparation workers (Occupational code: 35-2021), for example, was 289.3 per 10,000 FTE, which was more than three times the IR for all private industry (BLS, 2020c). As might be expected, cuts and lacerations were common among food preparation workers (IR = 81.9/10,000 FTE vs. 7.1/10,000 FTE for all private industry) (BLS, 2020c). However, the IRs among food preparation workers for sprains/strains/tears (63.3/10,000 FTE) and for soreness/pain (44.3/10,000 FTE) were each greater than IRs for these outcomes across all private industry (28.9/10,000 FTE for sprains/strains/tears and 15.4/10,000 FTE for soreness/pain) (BLS, 2020c). The total IR among waiters and waitresses (Occupational code: 35-3031) was 51.5/10,000 FTE, which was almost half of the IR for all private industry, and less than one-fifth of the IR for food preparation workers (BLS, 2020c). For soft tissue injuries, this trend is similar as the IRs among waiters and waitresses (10.6/10,000 FTE for sprains/strains/tears and 9.3/10,000 FTE for soreness/pain) (BLS, 2020c).

1.2. Fatigue

Fatigue has been identified as a risk factor for acute injuries in the workplace and is associated with chronic and acute illnesses (Kinali et al., 2016; Shen et al., 2006). However, fatigue has many definitions and no single measurement method has been identified as a "gold standard" (Dawson et al., 2011). Fatigue has been described as a decline in muscle performance due to muscle activity (Allen et al., 2008). Fatigue has also been defined as time-dependent reduction in maximal force generation during exercise (Gandevia et al., 1988). Furthermore, if one defines fatigue as a mood state, fatigue can be considered the feeling of having reduced capacity to perform and complete physical and mental activities (O'Connor, 2004). Mental or cognitive activity can also vary across job tasks. Workers performing cognitive tasks experience effects in their motivation and energy levels (Puetz, 2006). In order to anticipate the effects of fatigue and be able to control for it, it is important to acknowledge how fatigue can be differentiated. Fatigue can be differentiated into acute or chronic, central or peripheral, whole body or localized muscle, and physical or mental (Cavuoto & Megahed, 2016).

As described in Marino et al. (2011), the first accounts of fatigue were reported in the 1800s and early 1900s with Angelo Mosso describing two characteristics of fatigue: the reduction in muscular force and the physical sensation felt in a fatigued state. Further research has observed the existence of lactic acid after continuous muscle exertion. From these first accounts, research has increased on the cellular mechanisms and the physiological manifestations of fatigue. There are many different possible mechanisms contributing to muscle fatigue. However, for fatigue to manifest, work needs to be performed. For a muscle to perform work, a contraction is needed. A muscle contraction occurs during an electrical excitation (stimulus), and this sequence has been described as excitation-contraction coupling; this sequence is well-understood (Allen et al., 2008). Excitation-contraction coupling is the pathway to muscle contraction and, therefore, force production and movement (Sandow et al., 1952).

Westerblad et al. (1991) describes the physiological pathway to muscle activation. Muscle activation has different points that can be compromised and susceptible to a failure which could be attributed to muscle fatigue. This pathway first starts at the brain where a signal activates alpha-motoneurons that lead to an action potential conduction located at the neuromuscular junction. This action potential activates the release of acetylcholine from the nerve causing an electrical depolarization of the surface membrane of the cell. The depolarization then activates the sodium-potassium channels present in the cellular membrane which initiates another action potential that moves along the surface membrane into the transverse tubular system. Action potentials of T-tubules trigger the release of calcium ions from the sarcoplasmic reticulum to the myoplasm. The now available calcium ions bind to troponin-C, causing the removal of tropomyosin from actin active sites. The interaction between actin and myosin causes these filaments to slide and contract. This interaction has been known as the sliding filament theory. A pump dependent on adenosine triphosphate (ATP) transports the calcium ions back to the sarcoplasmic reticulum. When this release of calcium ions into the myoplasm stops, free calcium ions in the myoplasm are reduced due to the transport back to the sarcoplasmic reticulum. This causes the removal of calcium ions from troponin-C, ending the sliding interaction between actin and myosin to allow muscle relaxation (Westerblad et al., 1991; Cooke, 2004).

Modern research is investigating oxidative stress and its relationship with skeletal muscle fatigue. Reactive oxygen species are generated during the contraction of skeletal muscle. Delayed onset of muscle fatigue can occur due to antioxidants in the human body. Reactive oxygen species target the excitation-contraction cycle at the points of sarcolemma function, calcium regulation and transport, actin and myosin interaction, and mitochondrial functions (Reid, 2008). Existing interactions that have been observed that could affect muscular contraction include: inorganic phosphates and calcium ions, lactate and hydrogen ions, ATP and $Mg2^{+}$, ATP and PCr, blood glucose and glycogen, and blood flow (Allen et al., 2008; Fitts, 1994).

Central fatigue occurs because of a malfunction in the central nervous system (CNS) where signal transmission does not occur to the peripheral nervous system (PNS). Prolonged physical activity, even with lower demands, has resulted in CNS failures. Peripheral fatigue is identified with malfunctions in the PNS. An example of a PNS malfunction is negatively affected neuromuscular transmission occurring at the motor-end plate (Shen et al., 2006). Peripheral fatigue has been observed to occur due to activities of higher intensity (Yung, 2016).

In addition to physical muscular fatigue, workers experience cognitive fatigue. Ongoing research is examining the relationship between physical and cognitive fatigue. Cognitive fatigue has definitions pertaining to sleepiness, attention, motivation, arousal, and alertness (Yung, 2016). Sleep is an important element of recovery and maintaining the body’s homeostasis, and research indicates that adults generally require 7-9 hours of sleep per night (Consensus

Conference Panel, 2015). Time awake, brain use, time on task, circadian rhythm, total sleep duration, and sleep quality have been examined as determinants of sleepiness (Åkerstedt et al., 2009). Existing studies have observed levels of sleepiness to be affectedn both day and night shifts; this may occur due to recovery time between work shifts and other individual factors. Lack of energy and lack of motivation are correlated with sleepiness and have been observed to increase during shifts at night (Shadid et al., 2010; Åhsberg, 2000).

By understanding how fatigue occurs, there can be implications for dealing with it in the workplace. González et al. (2003) states, "Improved ergonomics have been shown to directly reduce levels of mental and physical fatigue and indirectly improve health outcomes, quality and efficiency of production, and other aspects of profitability."

1.3. Fatigue as a Precursor to Acute and Chronic Injuries at the Workplace

Muscular fatigue has been observed to be a precursor to injuries and illnesses. The issue is that fatigue does not always end one's execution of a task, but it does affect one's ability to perform the task (Enoka & Duchateau, 2008). Fatigue has been found to adversely affect motor control of both the upper and lower extremities and to reduce power output and force production (Barbieri et al., 2013). Workers experiencing less power and force capacity may need to use a work-around for their task, eliciting different movement strategies that may lead to a decrease in the safety of the task. Muscle fatigue due to lower levels of muscle stimulation could be due to the failure in the excitation-contraction coupling mechanism as previously described which may be a possible precursor to musculoskeletal disorders (MSDs) (Adamo et al., 2002). MSDs are non-acute illnesses involving the muscles, joints, nerves, tendons, cartilage, and spinal disks (Centers for Disease Control and Prevention [CDC], 2020). Risk factors for MSDs are broadly categorized as physical, psychosocial/work organizational, and personal. MSDs are soft tissue injuries that occur due to the exposure of force, repetitive motion, mechanical vibration, and non-neutral postures (physical risk factors). Thirty percent of non-fatal occupational injuries and illnesses are classified as MSDs and the median days away from work caused by MSDs was twelve days in 2019 (BLS, 2020b).

Mental fatigue has also been associated with an increased risk of injury, a decrease in work efficiency, decrements to work performance, and poor decision-making (Cavuoto & Megahed, 2016; Kumar, 2001; Williamson et al., 2011). As discussed previously, sleepiness can cause longer reaction times, larger performance variability and inconsistency, long response lapses, and an increase in human error which can lead to acute incidents occurring on the job (Åkerstedt et al., 2009; Costa, 2003; Shadid et al., 2010). These symptoms of cognitive fatigue may affect an individual's performance and cause an event leading to injury (Fan & Smith, 2017).

Fatigue may eventually be used as an indicator of exposure to ergonomic risk factors. Fatigue may also be used as risk indicator and design tool due to its association with worker productivity and production quality (Yung, 2016). The understanding of how fatigue develops in workers and its effect on the performance of work will be essential to keeping workers healthy.

1.4. Intervention and Strategies for the Prevention of Injuries and Illnesses

The Centers for Disease Control and Prevention (CDC) and the National Institute for Occupational Safety and Health (NIOSH) dedicate research towards workplace safety dedicated to ergonomics and musculoskeletal disorders. Research performed in the field of ergonomics aids in the recommendation of workplace system design and safety.

The Occupational Safety and Health Administration (OSHA), established in 1970, promulgates and enforces standards for controlling exposures to identified occupational hazards.

The major issue within workplace ergonomics and specifically fatigue is that an enforceable exposure standard does not exist yet. Furthermore, there are no quantitative standards of fatigue that can be used.

Reducing injuries at work requires commitment from all associated parties, including the workplace itself for placing an emphasis on worker safety. NIOSH provides workplace recommendations for a successful ergonomics program. These elements include identifying risk factors, training management and workers, collecting evidence, and implementing the program. Implementation involves using the hierarchy of controls for intervention. Implementation is followed up by evaluation of the program (CDC, 2017). These programs can be implemented in a workplace if desired and the resources exist. There are ways to focus on worker health while still valuing the production of the business.

1.5. Methods of Measuring Fatigue

Numerous objective measures of both cognitive and physical fatigue have been reported. For cognitive fatigue, different measurements of arousal, alertness, attention, vigilance, working memory, stress, motivation, and cognitive control have been made (Yung, 2016). Physiological measurements include heart rate (HR), heart rate variability (HRV), electromyography (EMG), electroencephalogram (EEG), mechanomyography (MMG), body temperature, respiration rates, and blood pressure (Yung, 2016). Blood sampling and muscle biopsies are used in the lab as gold standard measurement methods of fatigue (Garde et al., 2003). Research studies performed in the lab provide valuable information, as some of the previously listed objective methods are too invasive and are not feasible to be performed in the field.

Self-reported measures are noninvasive and provide important information about the worker and perceived fatigue. When paired with objective measures, self-reported measures can provide a secondary view of the data and allow more analysis to be performed. Objective measures are incredibly useful; however, they do not provide any descriptions of the feelings of fatigue. The participants' opinions and personal feelings can be useful in understanding the effects of fatigue. Not all individuals experience similar effects of fatigue, so self-reported fatigue can provide a better idea as to how someone is feeling. Self-report measures of fatigue that have been used and validated in previous studies are the NASA-TLX, ratings of perceived exertion (RPE), multidimensional assessment of fatigue (MAF), the visual analog scale for fatigue (VAS-F), and the Swedish Occupational Fatigue Inventory (SOFI) (Yung, 2016).

The Swedish Occupational Fatigue Inventory (SOFI) was created as a self-report measure to assess physical and cognitive fatigue among workers at their workplaces. This assessment was created as an advancement from a unidimensional to a multi-dimensional approach to measuring fatigue and has been further validated after its creation (Åhsberg et al., 1997; Åhsberg et al., 1998). The SOFI measures five different factors (subscales) of fatigue (physical exertion, physical discomfort, lack of motivation, sleepiness, and lack of energy). Physical exertion and physical discomfort evaluate the physical effects of fatigue, while sleepiness and lack of motivation are measures of cognitive fatigue. All correlations between factors were significant except the correlation between sleepiness and physical exertion. Lack of energy was found to correlate strongly with the other four factors (especially lack of motivation) which could allude to the future possibility to use this factor as a primary indicator for both physical and cognitive fatigue. In addition, sleepiness correlated highly with lack of motivation. Each factor consists of four verbal expressions related to that factor which are measured on a 0-6 Likert scale. Table 1 provides descriptions of each SOFI factor category, taken directly from Åhsberg (2000). Table 2 is an example of a SOFI questionnaire which presents the different expressions used in the questionnaire. Each SOFI subscale score is derived as the mean of the responses to the four items comprising the subscale. Table 3 separates each expression into its corresponding fatigue factor.

Table 1. Description of each SOFI factor.

Factor	Description
Physical exertion	Describes whole body sensations that may be the result of dynamic work and to a certain extent a sign of metabolic exhaustion.
Physical discomfort	Describes more local bodily sensations that may result from static or isometric workload.
Lack of motivation	Describes feelings of not being involved or enthusiastic.
Sleepiness	Describes feelings of sleepiness.
Lack of energy	Describes general feelings of diminished strength.

Table 2. Example SOFI questionnaire with expressions used and possible responses for each item.

Item	Expression	Not at all 0	1	2	3	4	5	To a very high degree 6
1	Palpitations	0	1	2	3	4	5	6
2	Lack of concern	0	1	2	3	4	5	6
3	Worn out	0	1	2	3	4	5	6
4	Tense muscles	0	1	2	3	4	5	6
5	Falling asleep	0	1	2	3	4	5	6
6	Numbness	0	1	2	3	4	5	6
7	Sweaty	0	1	2	3	4	5	6
8	Spent	0	1	2	3	4	5	6
9	Drowsy	0	1	2	3	4	5	6
10	Passive	0	1	2	3	4	5	6
11	Stiff joints	0	1	2	3	4	5	6
12	Indifferent	0	1	2	3	4	5	6
13	Out of breath	0	1	2	3	4	5	6
14	Yawning	0	1	2	3	4	5	6
15	Drained	0	1	2	3	4	5	6
16	Sleepy	0	1	2	3	4	5	6
17	Overworked	0	1	2	3	4	5	6
18	Aching	0	1	2	3	4	5	6
19	Breathing heavily	0	1	2	3	4	5	6
20	Uninterested	0	1	2	3	4	5	6

Table 3. SOFI expressions separated into each factor of fatigue.

Factor	Expression
Physical exertion	Palpitations Sweaty Out of breath Breathing heavily
Physical discomfort	Tense muscles Numbness Stiff joints Aching
Lack of motivation	Lack of concern Passive Indifferent Uninterested
Sleepiness	Falling asleep Drowsy Yawning Sleepy
Lack of energy	Worn out Spent Drained Overworked

The SOFI has been used for multiple purposes to study fatigue. It has been used in hospital settings for patients (Åhsberg & Fürst, 2001; Johansson et al., 2008). Gutiérrez et al. (2005) used a Spanish version of the SOFI to study fatigue levels among 240 nurses and found that shift duration was associated with sleepiness. Lee et al. 2021 used an adapted Korean version to study construction workers. Åhsberg (2000) further validated the original SOFI by studying teachers, cashiers, bus drivers, firemen, and locomotive engineers. There are opportunities for many fields where the SOFI can be applied and used as a viable option for studying worker fatigue.

1.6. Economics and Profits in the Restaurant Industry

The restaurant industry's impact on the U.S. economy has consistently increased since the 1970s. Over the last decade, restaurant industry sales have gone from $590 billion in 2010, to $833 billion in 2018 (National Restaurant Association, 2019). The restaurant industry is an essential part of people's lives and the tourism industry around the world. It is expected to grow over the next decade as the National Restaurant Association projects $1.2 trillion in sales in 2030 (National Restaurant Association, 2019). Growth in the industry is due to socialization, convenience, and high-quality service and food.

Customer loyalty is essential for a restaurant as it increases long-term sales and profits (Han & Ryu, 2009). Loyal customers are more likely to positively impact the restaurant by spending more money over longer periods of time and perform word-of-mouth behaviors when compared to non-loyal customers (Gupta et al., 2007; Han & Ryu, 2009). However, to have loyal customers, customer satisfaction is needed.

Factors that have been found to affect customer satisfaction include price perception, product quality, physical surroundings, and quality of service (Alhelalat et al., 2017; Gupta et al., 2007; Han & Ryu, 2009). Gupta et al. (2007) created a guest satisfaction survey addressing five categories of the restaurant experience. These five categories are greeting, service, food, value, and restaurant. The survey addresses factors such as speed, appearance, accuracy, attentiveness, attitude, and friendliness. According to Alhelalat et al. (2017), employee interaction has the biggest influence on customer satisfaction when compared to all other factors. If fatigue affects a worker's mood, motivation, or vigilance, this can adversely affect a worker's interaction with a customer and thus decrease customer satisfaction. A decrease in customer satisfaction can cause customers to not come back to the restaurant, which can decrease profits for both the individual worker and the restaurant.

1.7. Characteristics of Restaurants

Restaurants contain many occupational hazards and risk factors for fatigue due to the variety of work characteristics and tasks. The restaurant industry ranks third in total count of injuries and illnesses consisting of more than 100,000 nonfatal cases (Huang et al., 2012). Between front of house workers and back of house workers, there are multiple different mechanisms for injury or illness. Workplace hazards include slips, trips, and falls, burns, high temperatures, nonstandard working hours, long work shifts, non-neutral postures, repetitive tasks, high loads that can be coupled with non-neutral postures, and limited opportunities for breaks and recovery (Jahangiri et al., 2019). In a study of 100 restaurant servers, participants identified slips/trips/falls, burns, cuts, and back injuries as the most common threats to workplace health and safety (Dempsey & Filiaggi, 2006). Wills et al. (2013) observed a breakdown of shift activity for servers where 24.5% of a shift was spent sitting, 30.9% of a shift was spent walking, and 44.6% of a shift was spent standing.

Typical working hours are long; a double shift is often a routine occurrence for some workers. Workers can be scheduled multiple days in a row, even closing one night then opening the next morning. Hours can begin early in the day or go late into the night, and hours of operation will depend on the restaurant and day of the week. Many states require restaurants to close at 2:00 am; however, some states and cities with a busier nightlife allow operation until 3:00 am and even 4:00 am. As previously discussed, shift work and these work hours can affect the circadian rhythm of a worker and therefore their recovery, possibly leading to fatigue (Åkerstedt et al., 2009).

Worker demographics can vary at different restaurants. It is a popular occupation for people of all ages because of the nonstandard working hours and opportunity for making cash tips to take home instead of having to wait for a biweekly check. The nonstandard working hours of evening shifts and weekend shifts allow the possibility of a restaurant job to be a secondary source of income for individuals. Due to the busy seasons for restaurants (summer and holidays), these align with the school year thus providing opportunities to students for a seasonal role within restaurants.

There are different tasks a restaurant staff member will perform during a work shift. Servers and bartenders can expect to serve their patrons by pouring drinks and carrying food, clean glassware, roll silverware, change kegs and soda boxes, and fill ice buckets, among other side work tasks. Cooks can expect to cut and prepare food items, cook food, wash dishes, and clean the kitchen area. Repetitive motions of the upper limbs for their required tasks can be expected for cooks (Xu & Cheng, 2014). Due to the high variation of tasks and their associated demands, it can be difficult to quantify risk from these tasks (Dempsey & Filiaggi, 2006).

1.8. Fatigue in Restaurants

There are not many fatigue-based studies in the restaurant industry, especially studies that use both objective and self-report measures simultaneously. Gentzler & Smither (2012) studied 9 servers at a country club restaurant studied by conducting ergonomic assessments pertaining to physical (MSD risk formula, physical exertion questionnaire) and cognitive workload (self-report cognitive workload scale). They found that the tasks of carrying/lifting and polishing were both at a moderately high risk with respect to MSDs. Kokane & Tiwari (2011) performed a cross-sectional study among 15 restaurants (n=127) on the health of the staff at each restaurant. 14.2% of the workers exhibited MSD symptoms and 7.9% workers had burn scars from their job role. 57.5% of the participants reported no adverse health outcomes.

Working hours and psychological health was studied in Japan comparing restaurant workers (n=753) to office workers (n=354) using a questionnaire. Although the number of working hours was found to increase negative emotions and decrease concentration, no difference between restaurant workers and office workers was observed. However, among the restaurant workers, a linear association observed between working hours and fatigue (Otsuka & Tatemaru, 2010).

A study performed in nine restaurants (n=180) in Indonesia used a translated version of the SOFI to measure fatigue between the same job role in different restaurants. Fatigue levels of restaurant employees were found to be mild to moderate (Zuraida & Iridiastadi, 2015). Wills et al. (2013) examined loads on different body parts of servers (n=20) and their possible effect on joint discomfort throughout a single work shift using a current symptom survey. Almost all joints were found to have an increase in discomfort between the start and end of the shift not including the shoulders and knees. The upper back, lower back, and neck were observed to have the highest increase in perceived discomfort.

Jones et al. (2005) studied physical demands of differing job roles (servers, bartenders, cooks) in three neighborhood pubs (n=17). There were three separate visits to the pubs for data collection lasting two hours each visit on three tasks identified as highest load risks. Bartender tasks identified as high load were keg movement, pouring pitchers, and high reaching motions. Waitress tasks studied were food/drink carrying, tray lifting, and stooping for delivering items to tables. Cook tasks studied were onion lifting (handling of bags/boxes of food), high reaching, and a gravy pull task (similar to moving a large bucket full of liquid). Bartenders were observed to be at the highest risk of injuries due to their required tasks. Servers were observed to be at a higher risk for injury when compared to cooks. However, only three tasks for each job role were examined, and only load and posture were studied as risk factors.

1.9. Objectives

Existing literature has identified a large working population, elevated injury rates, risk factors for fatigue, and the restaurant industry's essential contribution to the economy. However, risk factors and their effects of fatigue have not yet been thoroughly examined in restaurant settings. The aim of this research is to examine the effect of job role on self-reported fatigue and to examine the effect of job role on the temporal relationship between occupational physical activity and self-reported fatigue among restaurant workers. Restaurant roles examined in this study were cooks (back of house) and servers (front of house). To do this, each participant was studied for three shifts. The participants wore two inertial measurement units (IMUs) to collect physical activity data as an objective measure, while also completing the SOFI questionnaire throughout their shift as a measure of self-reported fatigue. This research study hopefully will help future models of fatigue and mitigations for injuries and illnesses for restaurant workers.

CHAPTER TWO: FATIGUE AMONG RESTAURANT WORKERS

2.1. Introduction

The restaurant industry is a popular occupation for workers of all ages as a primary and secondary source of income. The amount of people employed in the full-service restaurants (NAICS Code: 722511) is an estimated 12.5 million people in 2020 (National Restaurant Association, 2020; U.S. Census Bureau, 2017). Due to the size of the occupational group, the restaurant industry ranks third among those with more than 100,000 nonfatal injury and illness cases (Huang et al., 2012). While in 2019 the nonfatal occupational injury and illness rate (IR) of 2.7 cases per 100 full-time equivalent workers (FTE) in full-service restaurants was similar to the IR for all private industry of 2.8 FTE (BLS, 2020a), substantial differences in IR were observed across restaurant job roles. For example, the IR for cuts and lacerations for cooks was 31.5 per 10,000 FTE while the IR for waiters and waitresses was 9.4 per 10,000 FTE (BLS, 2020c).

Restaurant workers endure various working conditions such as non-standard and long working hours, variance in shift schedules, and limited shift rest breaks which can affect fatigue levels felt for the staff members (Jahangiri et al., 2019). However, there has been little research in restaurants examining the health and safety of the restaurant workers due to the characteristics of their work. Furthermore, there is still limited research on the short and long-term effects of fatigue on a worker and the possible use of fatigue as an indicator for those health outcomes.

Measuring fatigue is difficult. Self-reported fatigue measures are usually performed due to their feasibility during work shift. The non-invasiveness of self-reports make them easier to perform during a study when compared to some objective measures such as heart rate variability (HRV), electromyography (EMG), and blood sampling (Garde et al., 2003; Yung, 2016). Measuring fatigue is important as it has been associated with adverse effects on physical and cognitive functions (Aryal et al., 2017). Physical activity data can be measured and used to estimate one's physical workload and possibly their fatigue levels. These physical activity measures coupled with measures of cognitive fatigue may be able to provide a picture of worker fatigue levels during a work shift. The estimate of fatigue levels during a work shift is enhanced when measurements are taken for a full shift.

When performing fatigue measurements, it is important to not interrupt the normal workflow of the worker as best as possible to capture accurate data, which can be challenging. Measurements need to be easy and quick to perform so work is not affected. Accelerometers and inertial measurement units (IMUs) are used in the field to measure continuous physical activity data. These can be placed on the body of the worker and remain there for an entire shift capturing physical activity data without interfering with the work. Fatigue may eventually be able to be used as an indicator for long and short-term health outcomes, thus it is important to examine its exposures in different job settings to predict possible adverse health outcomes.

Despite the large restaurant industry workforce, relatively little evidence exists to ascertain whether the observed differences injury risk among different restaurant occupational roles may be related to differences in the experience of fatigue. In this study, we hypothesized that the within-shift manifestation of self-reported fatigue, as assessed using the Swedish Occupational Fatigue Inventory (SOFI; Åhsberg et al., 1997; Åhsberg, 2000), depended on job role (i.e., servers vs. cooks). We also explored the effects of time since the start of the shift and the interaction between time and job role on measures of both self-reported fatigue and physical activity levels, as well as relationships between self-reported fatigue and physical activity levels.

2.2. Methods

2.2.1. Study Setting and Participants

All data collection procedures occurred at a single full-service restaurant in Southeast Michigan with approximately 30 employees over the course of 18 days from mid-March to early April 2021. The restaurant has a capacity of 198 patrons and sits on a public golf course, sharing its building with the golf course pro shop. The front of the house includes a main dining room, bar area, side patio, and front patio. There are three serving computer stations, one near the main entrance, one near the bar/kitchen, and one near the side patio. There is also one computer behind the bar. The back of the house consists of the food cooking stations, a dishwashing area, a food preparation area, cooler, and dry storage. The basement houses another cooler where alcohol cans, bottles, and beer kegs are kept, along with another freezer for food and a supply room.

All employees were invited to participate in the study. Study participants represented both front and back of house job roles. "Servers" (n=8 total) included wait staff (n=7, 5 female and 2 male) and one bartender (female), and "cooks" (n=5, all male) included those working in the kitchen. All participants were screened for symptoms consistent with SARS-CoV-2 infection prior to and during study procedures. Eligibility criteria also included: age (18+ years), the availability of a phone with SMS messaging, and the absence of work-limiting musculoskeletal pain during the previous two weeks. Participants self-reported height and weight, from which body mass index (BMI) was calculated. Participants also reported the number of years working at the restaurant and the total number of years worked as a server or cook (as appropriate). Table 4 includes demographic information of the participants. For each participant, data collection occurred during three consecutive work shifts, although the shifts did not need to be on consecutive days. Participants were paid $15 per shift (i.e., $45 for the completion of the entire study) and all study procedures were approved by the University of Iowa Institutional Review Board (IRB# 202009416).

Table 4. Demographic information, by job role.

	Total (n=13)		Servers (n=8)		Cooks (n=5)	
	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)
Female	6 (46)		6 (75)		0 (0)	
Male	7 (54)		2 (25)		5 (100)	
Age (years)		33.5 (11.1)		31.0 (18.5)		37.4 (4.7)
BMI (kg/m^2)		24.7 (4.1)		26.2 (4.7)		22.3 (1.1)
Years at study site		6.1 (0.4)		5.1 (5.3)		7.8 (5.4)
Years in job role		9.2 (8.2)		7.4 (7.6)		12.0 (9.3)

2.2.2. Self-reported Fatigue

Before, during, and after each shift, information about self-reported fatigue was collected with the Swedish Occupational Fatigue Inventory (SOFI) (Åhsberg et al., 1997; Åhsberg, 2000). The SOFI is a 20-item questionnaire, with four items used to measure each of five fatigue dimension subscales (lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness). Each item is scored on a discrete 0 to 6 scale, with written anchors at 0 ("not at all") and 6 ("to a very high degree"). Subscale scores are then derived as the mean of the ratings for each of the four items (yielding a possible range of scores of 0 to 6 for each subscale) and were analyzed as continuous variables.

An electronic version of the SOFI was created in Qualtrics and surveys were delivered to participants' phones using the University of Iowa's Dispatch communications service. Custom links to the electronic SOFI in Qualtrics were made for each instance of survey administration for each participant; the order of the SOFI questions was randomized for each custom link.

For servers, the first SOFI questionnaire was distributed at the beginning of the work shift. After this first questionnaire, a SOFI questionnaire was distributed every hour until the end of the shift. The end of the shift consisted of an exit SOFI questionnaire taken right after the servers clocked out. Cooks also completed the SOFI questionnaire at the beginning of the shift similar to the servers. However, due to safety and logistical concerns for the kitchen staff, the SOFI was distributed only two more instances after arriving. The second SOFI questionnaire was completed during a break in the middle of the shift, typically following the lunch rush for day shifts and following the dinner rush for night shifts. These questionnaires were distributed as close to the rushes as possible to attempt to get the best estimate of fatigue for those time periods. Then, the exit SOFI was completed following clock out, similar to the servers.

Even though a SOFI questionnaire was distributed, participants did not necessarily respond immediately. The goal was to avoid disruption to the workflow of the whole restaurant, so participants were instructed to respond as soon as feasibly possible. In Qualtrics, a timestamp was available for every SOFI response, allowing the calculation of time since the start of the shift to the completion of each survey.

2.2.3. Physical Activity

For each participant and shift, physical activity was measured with two inertial measurement units (IMUs) (GT9X Link, Actigraph LLC., Pensacola, FL), one located on the dominant wrist (and secured using a watch band) and the other located on the non-dominant hip (and secured using a belt clip). Two IMUs were used since a hip-worn sensor alone fails to capture activity associated with arm movement during hand/arm-intensive work activities. In the current study, we expected some restaurant work to be arm-intensive (e.g., cooks) while other restaurant work to involve more whole-body activity (e.g., servers). Each IMU recorded accelerometer (± 16 g), gyroscope (± 2000 deg/sec), and magnetic field strength (± 4800 μT) data. The magnetometer data were not used in the current study. Raw IMU data were sampled at 100 Hz and stored to on-board flash memory in the proprietary Actigraph file format. After each shift, the files were download to a computer using ActiLife software (version 6.11.9, Actigraph LLC, Pensacola, FL) and then exported to comma-separated text files for processing using LabVIEW (version 2017, National Instruments, Austin, TX).

In LabVIEW, and separately for the wrist-worn and hip-worn IMUs, physical activity was estimated in metabolic equivalent of tasks (METs) using the accelerometer and gyroscope data. Specifically, the Euclidean Norm Minus One (ENMO) was derived by first calculating the acceleration vector magnitude, then rounding negative values to zero, and then subtracting 1g (van Hees et al., 2013). Raw gyroscope data were low pass filtered (2nd order Butterworth, zero-phase, 35 Hz corner frequency) and the gyroscope vector magnitude (GVM) calculated from the filtered data. The ENMO and GVM values were each then averaged over non-overlapping windows of 1-second in duration. The averaged (1-sec) ENMO and GVM values were then combined to estimate 1-sec METs using polynomial regression models for intermittent activity (separate models for the hip and wrist IMU) reported in Hibbing et al. (2018).

For each participant and shift, the wrist and hip 1-sec MET values were categorized as "light" (≤3 METs), "moderate" (3 to 6 METs) or "vigorous" (>6 METs) intensity of physical activity. Then, the proportion of time in each physical activity intensity category (i.e., units of %time) was calculated for each interval between consecutive SOFI timestamps. Also, from the start of the shift to each timestamp associated with each SOFI response, the total accumulated METs ("total METs" hereafter) was calculated as the sum of the 1-sec MET time series (i.e., units of MET-sec); a value of 0 was assigned to the beginning of the shift since no physical activity had been accumulated at that instant. As a cumulative metric, total METs always increases as a shift progresses but to a greater extent during periods of moderate or vigorous activity in comparison to during periods of light activity. Thus, while total METs is strongly correlated with time since the start of a shift, the correlation is not perfect.

2.2.4. Statistical Analysis

A hierarchical linear, mixed-effect model was used to estimate the effects of job role (servers vs. cooks), time since the start of the shift (based on timestamps from SOFI administration, in hours), and the interaction between job role and time on each SOFI subscale (i.e., each subscale was analyzed separately as the dependent variable). Random model effects included participant (nested within job role) and shift (nested within participant). In addition, random intercepts and slopes (nested within both participant and shift) were included to accommodate between-subject variability in the temporal relationship between time since the start of the shift and SOFI subscale values (i.e., not every participant would be expected to begin a shift with the same level of a SOFI subscale [intercept] or report the same change in subscale value per hour of work [slope]). Analogous models were constructed for each physical activity summary measure from each IMU (i.e., wrist and hip) entered as the dependent variable, i.e., total METs and the proportion of shift with light, moderate, and vigorous activity.

Hierarchical linear, mixed-effect models were also used to estimate the effect of job role on the relationship between each physical activity summary measure (METs) (as an independent variable) and each SOFI subscale (as a dependent variable). As above, the models included job role, the physical activity summary measure, and their interaction as fixed effects, participant (nested within job role) and shift (nested within participant) as random effects, and random intercepts and slopes. All statistical procedures were performed in SAS (version 9.4, SAS Institute Inc., Cary, NC).

2.3. Results

The average shift duration was 7 hours and 1 minute (SD = 57 minutes) among servers and 7 hours and 19 minutes (SD = 1 hour, 1 minute) among cooks. The average number of SOFI distributions among servers was 7.5 (SD = 1.3) per shift, with a total of 180 SOFI responses across all shifts among the eight servers. As described previously, SOFI distributions for the cooks were constant at three per shift equaling, yielding a total of 45 SOFI responses.

Examples of the time series of 1-sec MET data for one server and one cook are provided in Figure 1 (for wrist sensor data) and Figure 2 (for hip sensor data). Of particular interest is that, when physical activity was measured at the wrist, the cook spent approximately four times the proportion of the shift with vigorous physical activity compared to the server (17.3 %time vs. 4.3 %time) but when physical activity was measured at the hip, the server spent approximately five times the proportion of the shift with vigorous physical activity compared to the cook (20.2 % time vs. 4.3 %time).

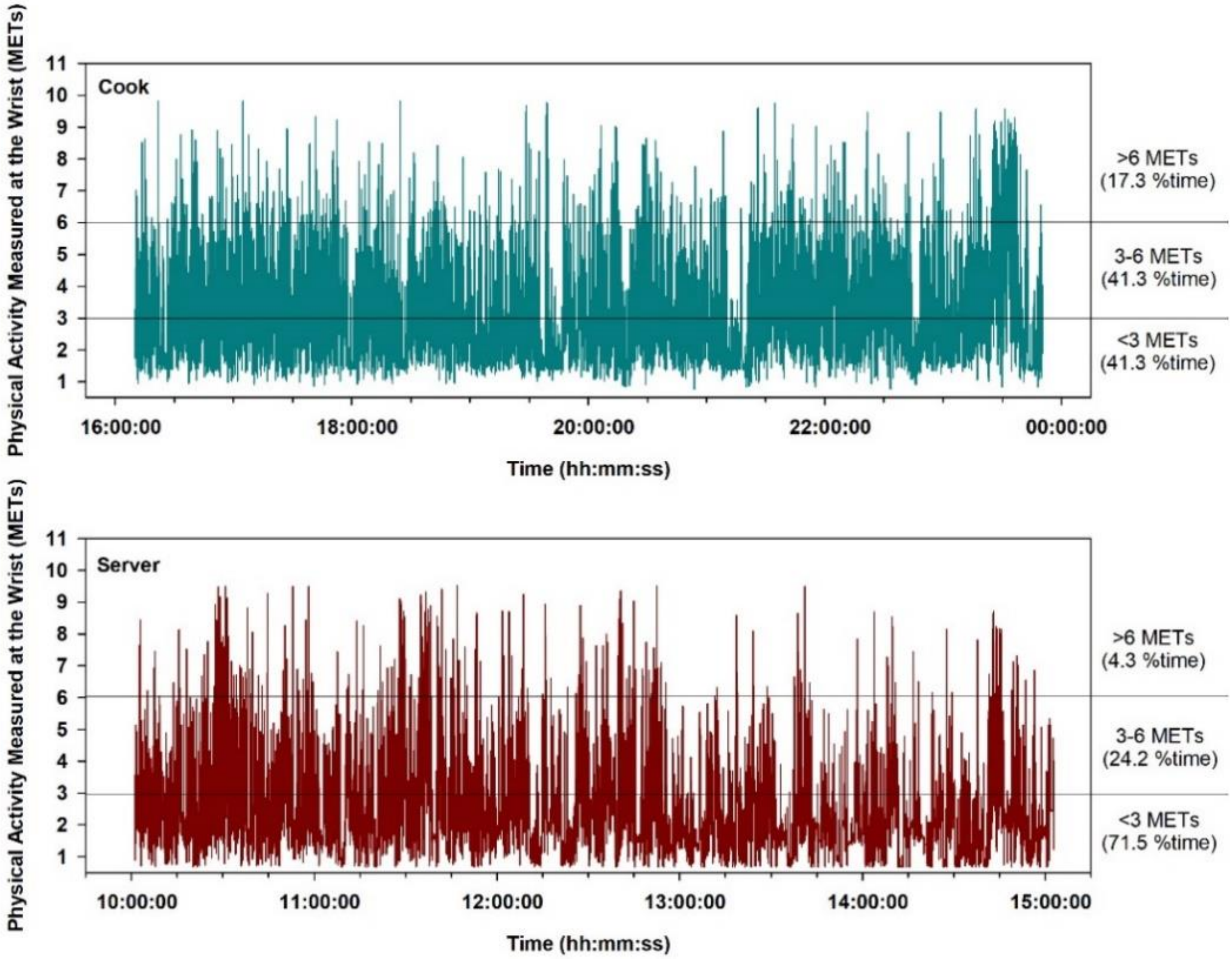

Figure 1. Wrist MET-sec data of one cook and one server with MET cut points and percent time spent in MET categories across one shift.

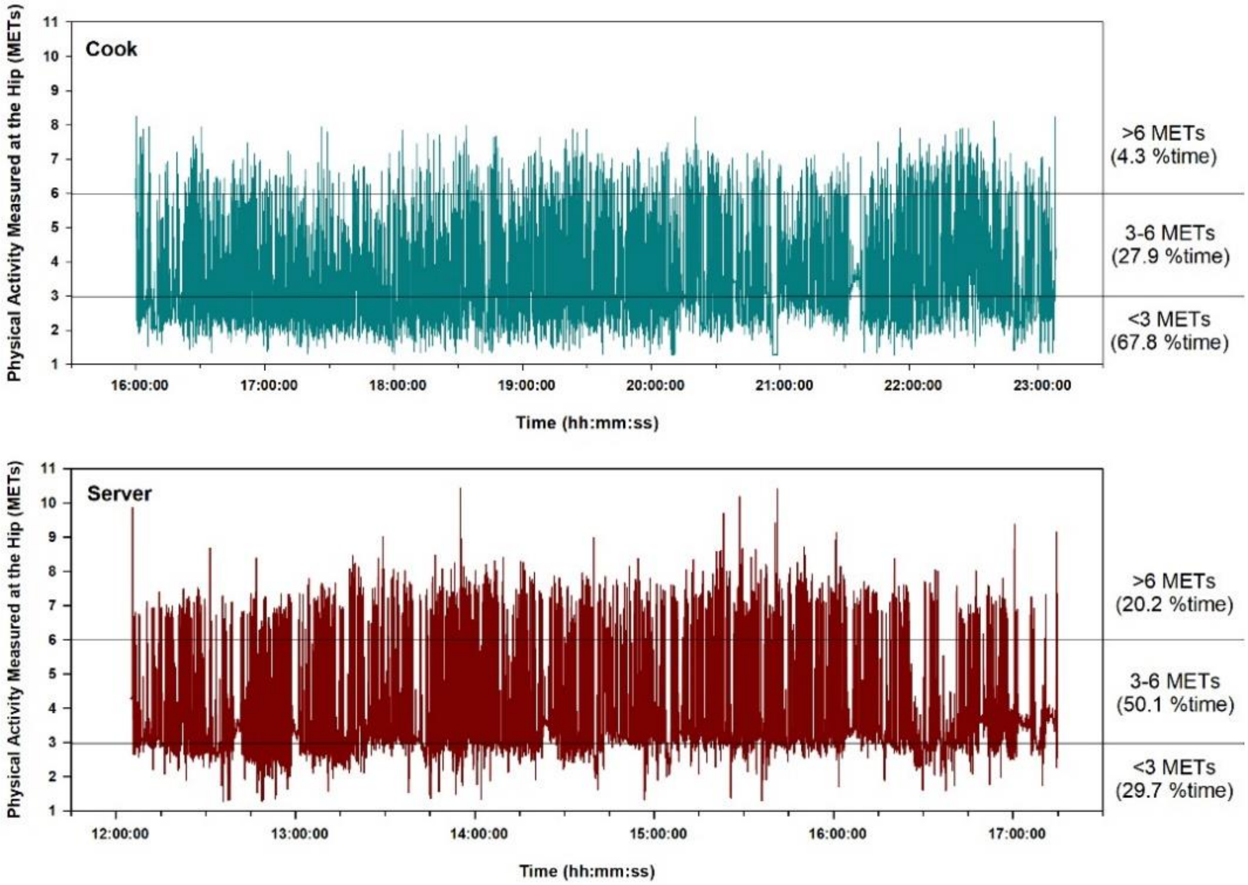

Figure 2. Hip MET-sec data of one cook and one server with MET cut points and percent time spent in MET categories across one shift.

Figure 3 shows SOFI sleepiness subscale ratings for one server and one cook throughout three shifts of observation, with sleepiness plotted as a function of time since the start of the shift (based on the timestamps accompanying the SOFI responses in Qualtrics). Inspection of the plot shows that for the server, sleepiness increased over the course of each shift (although with apparent variability) and on average across the three observed shifts. In contrast, for the cook, sleepiness showed little change either within one shift or on average across all three shifts.

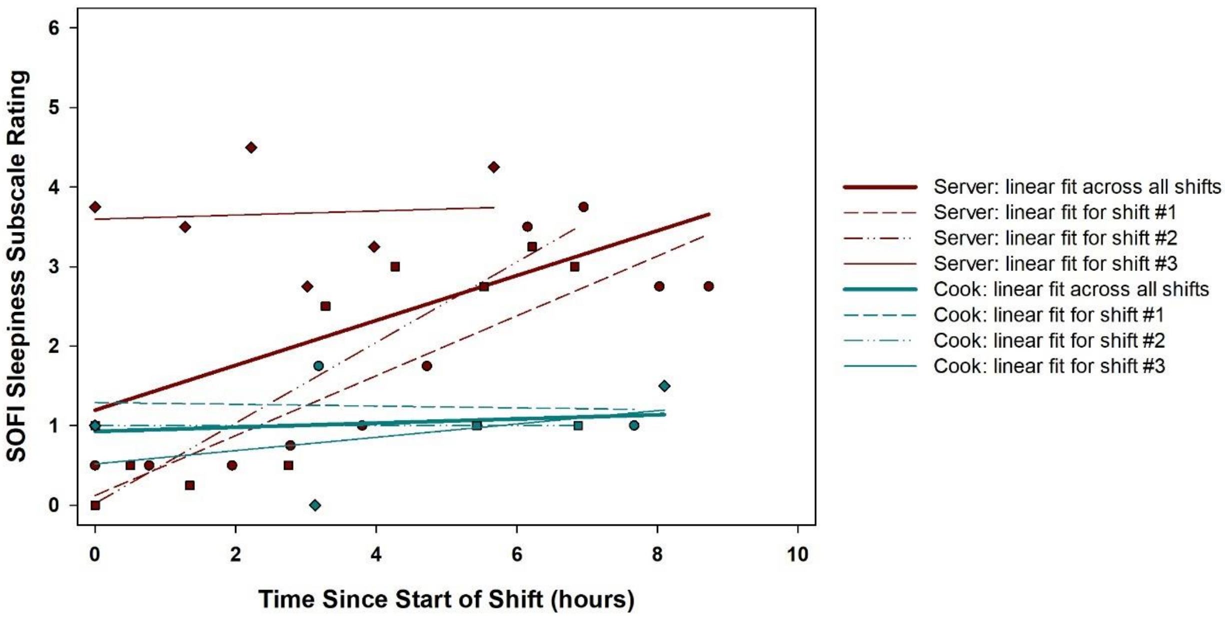

Figure 3. Sleepiness scores and their linear fit across each shift and all shifts for one cook and one server.

In Figure 4, the relationship between time since the start of the shift and sleepiness is shown by job role (i.e., the interaction between time and job role). The intercept is the sleepiness score at the beginning of the shift (hour 0), while the slope is the change in sleepiness per hour since the start of the shift. The bold linear fit lines reflect the overall relationship between time since the start of the shift and sleepiness for each job role, with 95% confidence intervals included as bold dashed lines. Note that Figures 3 and 4 are examples for the SOFI sleepiness subscales to demonstrate the progression from raw SOFI responses to statistical analyses; similar plots for the remaining SOFI subscales are not included.

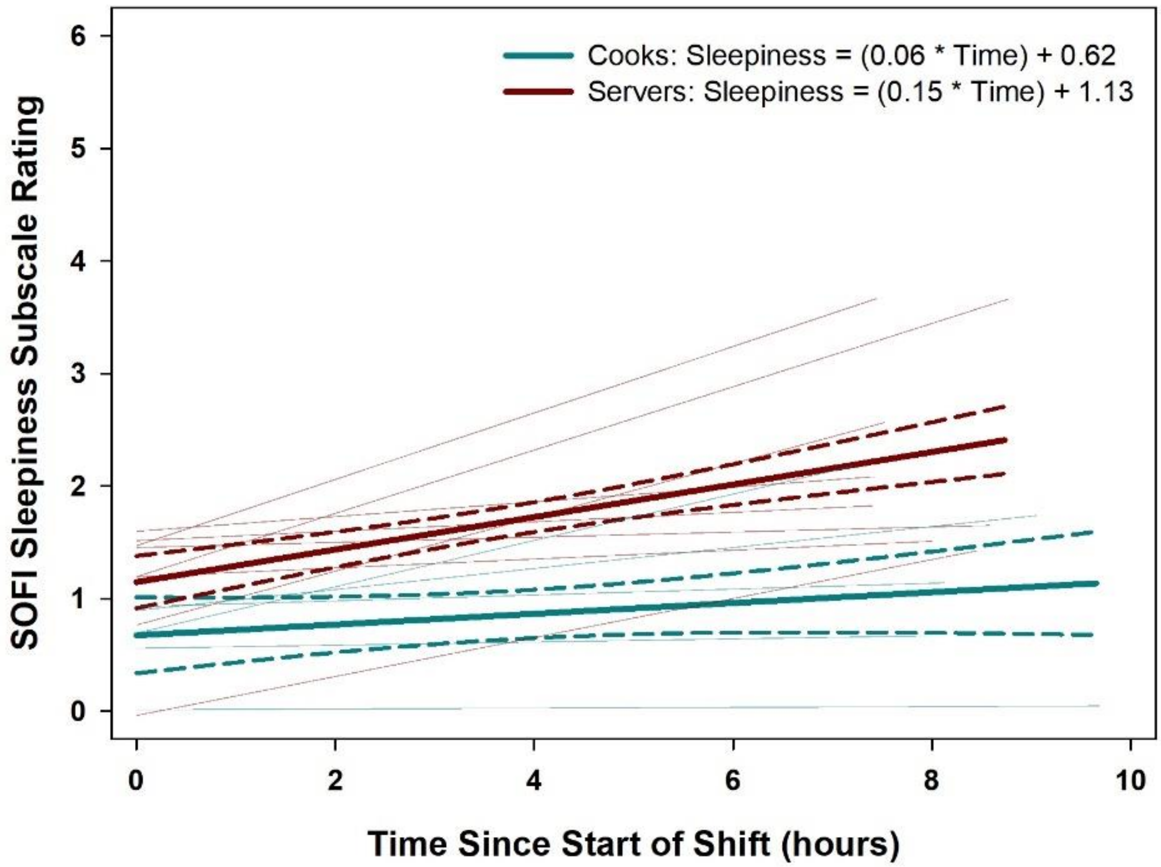

Figure 4. Sleepiness regression lines across all shifts for each participant and each job role.

Results of the statistical analysis of the effects of job role, time since the start of the shift, and their interaction (inter.) on the SOFI subscale scores are provided in Table 5. For each job role (servers and cooks), the intercept is the SOFI subscale rating at the beginning of the shift while the slope is the change in subscale rating per hour since the start of the shift. The *p*-value for each fixed effect (job role, time, interaction) is also shown. The "Job Role" column indicates the statistical significance of job role on each SOFI subscale score regardless of time since the start of the shift, the "Time" column indicates the statistical significance of time since the start of the shift regardless of job role, and the "Interaction" column indicates the statistical significance of the interaction between job role and time (i.e., whether the effect of job role on a SOFI subscale score depended on time since the start of the shift or, equivalently, whether the effect of time since the start of the shift depended on job role).

Table 5. The start of the shift (intercept) and rate of change per hour (slope) of each SOFI factor across one shift.

	Servers (n=8)		Cooks (n=5)		*p*-value		
SOFI Subscale	Intercept	Slope	Intercept	Slope	Job Role	Time	Inter.
Sleepiness	1.13[1]	0.15[2]	0.63[1]	0.06[2]	0.18	<0.01	0.01
Physical exertion	0.43[1]	0.02	0.75[1]	0.07[2]	0.18	<0.01	0.03
Physical discomfort	0.52	0.16[2]	1.68[1]	0.12[2]	0.09	<0.01	0.36
Lack of energy	1.46[1]	0.18[2]	1.03[1]	0.21	0.40	<0.01	0.49
Lack of motivation	1.26[1]	0.10[2]	0.91[1]	0.02	0.49	0.01	0.05

[1]Intercept statistically significantly different from 0.
[2]Slope statistically significantly different from 0.

The main effect of job role was not statistically significant for any SOFI subscale, although cooks appeared to exhibit greater physical discomfort than servers (p=0.09). The main effect of time showed a statistically significant increase for each SOFI subscale. Although statistically significant, the increases were modest in magnitude with a maximum of 1.46 units on the lack of energy subscale among servers (i.e., slope of 0.18 per hour multiplied by 8 hours). The interaction between job role and time since the start of the shift was statistically significant for the factors of sleepiness ($p = 0.01$), physical exertion ($p = 0.03$), and lack of motivation ($p = 0.05$). Sleepiness increased with time since the start of the shift among servers at more than twice rate than among cooks (slope: 0.15 per hour for servers vs. 0.06 per hour for cooks, $p = 0.01$). Similarly, lack of motivation increased with time since the start of the shift among servers at five times the rate than among cooks (slope: 0.10 per hour for servers vs. 0.02 per hour for cooks, $p = 0.05$).

The main effect of job role on the proportion of time spent in different categories of physical activity intensity is provided in Table 6. Significant differences between job roles were observed for each category when physical activity was measured at the wrist, with cooks exhibiting a greater mean proportion of time then servers with vigorous (13% vs. 8%, $p = 0.01$) and moderate (38% vs. 31%, $p = 0.01$) physical activity but a lower mean proportion of time with light (48% vs. 62%, $p < 0.01$) physical activity. However, when considering physical activity measured at the hip, servers exhibited a statistically greater mean proportion of time than cooks with vigorous (11% vs. 5%, $p = 0.01$) physical activity, while differences between job roles for the proportions of time with light and moderate physical activity were not statistically significant.

Table 6. Mean (sd) proportion of a work shift spent in different categories of energy expenditure, by job role and sensor location.

Energy Expenditure	Servers (n=8) Percent of Shift (sd)	Cooks (n=5) Percent of Shift (sd)	*p*-value
Wrist			
Light (≤3 METs)	61.6 (2.4)	48.5 (1.8)	<0.01
Moderate (3-6 METs)	30.5 (1.4)	38.3 (2.4)	0.01
Vigorous (>6 METs)	7.9 (1.2)	13.2 (1.4)	0.01
Hip			
Light (≤3 METs)	53.8 (5.2)	58.5 (11.1)	0.73
Moderate (3-6 METs)	35.4 (3.9)	36.6 (10.5)	0.91
Vigorous (>6 METs)	10.8 (1.7)	4.9 (1.16)	0.01

The average total wrist METs per shift among servers was 75,320 MET-sec (SD = 14,763 METs) and among cooks was 98,476 MET-sec (SD = 12,179 METs). The average total hip METs per shift among servers was 78,825 MET-sec (SD = 27,186 METs) and among cooks was 85,216 MET-sec (SD = 19,510 METs). Results of the statistical analysis of the effects of job role, total METs (i.e., the sum of the continuous1-sec MET data), and their interaction on the SOFI subscale scores are provided in Table 7 for the wrist sensor and in Table 8 for the hip sensor. Note that the slopes are scaled by 10,000 to improve interpretability, e.g., for sleepiness

(Table 7) the slope of 0.15 should be interpreted as the change in sleepiness of 0.15 units per a 10,000 unit increase in total METs. For context, if 1-sec MET values were at a constant value of 2.5 METs, 10,000 MET-sec would be accumulated in 4000 seconds (1.7 hours).

When predicting SOFI subscale responses (as the dependent variable) as a function of job role, total METs as measured at the wrist, and their interaction, the main effect of job role was not statistically significant for any SOFI subscale while the main effect of total METs was statistically significant for all SOFI subscales (Table 7). Servers appeared to experience an increase in sleepiness at three times the rate compared to than cooks (slope = 0.15 for servers vs. 0.05 for cooks), i.e., a statistically significant interaction ($p < 0.01$). Statistically significant interactions between job role and total METs were observed for the physical exertion ($p = 0.03$) and lack of motivation ($p = 0.01$) SOFI subscales. These results closely mimic those reported in Table 5, reflecting the correlation between time since the start of the shift and total METs.

Table 7. The effects of job role, total METs as measured at the wrist, and their interaction on SOFI subscale ratings.

	Servers (n=8)		Cooks (n=5)		*p*-value		
SOFI Subscale	Intercept	Slope	Intercept	Slope	Job Role	METs	Inter.
Sleepiness	1.11[1]	0.15[2]	0.62[1]	0.05[2]	0.19	<0.01	<0.01
Physical exertion	0.45[1]	0.01	0.74[1]	0.06[2]	0.22	<0.01	0.03
Physical discomfort	0.53	0.14[2]	1.67[1]	0.09[2]	0.09	<0.01	0.10
Lack of energy	1.44[1]	0.17[2]	1.05[1]	0.15[2]	0.44	<0.01	0.52
Lack of motivation	1.22[1]	0.01[2]	0.91[1]	0.02	0.55	<0.01	0.01

[1]Intercept statistically significantly different from 0.
[2]Slope statistically significantly different from 0.

When predicting SOFI subscale responses (as the dependent variable) as a function of job role, total METs as measured at the hip, and their interaction, the main effect of job role was not statistically significant for any SOFI subscale (although it approached statistical significance for the physical discomfort subscale, with cooks reporting greater levels than servers) while the main effect of total METs was statistically significant for all SOFI subscales (Table 8). The pattern of statistical significance for the interaction between job role and total METs was consistent to that observed previously, i.e., statistically significant interactions were observed for the sleepiness and lack of motivation SOFI subscales and nearly for the physical exertion subscale.

Table 8. The effects of job role, total METs as measured at the hip, and their interaction on SOFI subscale ratings

	Servers (n=8)		Cooks (n=5)		*p*-value		
SOFI Subscale	Intercept	Slope	Intercept	Slope	Job Role	METs	Inter.
Sleepiness	1.15[1]	0.13[2]	0.63[1]	0.05[2]	0.15	<0.01	<0.01
Physical exertion	0.41[1]	0.02	0.76[1]	0.06	0.13	<0.01	0.08
Physical discomfort	0.48	0.15[2]	1.72[1]	0.09[2]	0.07	<0.01	0.10
Lack of energy	1.44[1]	0.16[2]	1.07[1]	0.17[2]	0.44	<0.01	0.83
Lack of motivation	1.23[1]	0.09[2]	0.90[1]	0.02[2]	0.51	<0.01	0.02

[1]Intercept statistically significantly different from 0.
[2]Slope statistically significantly different from 0.

Tables 9-13 present the results of analyses predicting the SOFI subscale responses as a function of job role, the proportion of time spent in varying levels of physical activity intensity (as measured at both the wrist and the hip), and their interaction. For any physical activity intensity category, model intercepts are the SOFI subscale ratings when 0% of a shift is spent in that particular category and slopes reflect the change in SOFI subscale ratings per 10 unit increase in the %time spent in that particular category.

The main effect of job role was not statistically significant for any level of wrist or hip activity and their effect on sleepiness ratings (Table 9). The main effect of percent time spent in vigorous wrist activity statistically significant (i.e., sleepiness increased at the %time with vigorous wrist activity increased, regardless of job role). The interaction between job role and percent time spent in each level of wrist or hip activity was not statistically significant.

Table 9. Percent time spent in energy expenditure levels and its effect on self-reported sleepiness by job role and sensor location.

	Servers (n=8)		Cooks (n=5)		*p*-value		
Energy Expenditure	Intercept	Slope	Intercept	Slope	Job Role	% Time	Inter.
Wrist							
Light (≤3 METs)	4.39[1]	-0.05[2]	2.39	-0.03	0.32	0.06	0.78
Moderate (3-6 METs)	-0.27	0.06[2]	0.27	0.02	0.81	0.13	0.37
Vigorous (>6 METs)	0.80[1]	0.10[2]	-0.24	0.08	0.41	0.03	0.78
Hip							
Light (≤3 METs)	1.86[1]	-2.8E-3	1.37[1]	-0.01	0.53	0.37	0.67
Moderate (3-6 METs)	1.62[1]	2.6E-3	0.64	0.01	0.14	0.43	0.70
Vigorous (>6 METs)	1.59[1]	0.01	0.70	0.04	0.17	0.48	0.66

[1]Intercept statistically significantly different from 0.
[2]Slope statistically significantly different from 0.

The main effect of job role was not statistically significant for any level of wrist or hip activity and their effect on lack of motivation ratings (Table 10). The main effect of percent time spent in energy expenditure categories was statistically significant for moderate wrist activity. Servers experienced an increase in lack of motivation of 0.06 units per 10% of time spent in moderate wrist activity ($p = 0.03$). The interaction between job role and percent time was not statistically significant for any level of wrist or hip activity.

Table 10. Percent time spent in energy expenditure levels and its effect on self-reported lack of motivation by job role and sensor location.

	Servers (n=8)		Cooks (n=5)		*p*-value		
Energy Expenditure	Intercept	Slope	Intercept	Slope	Job Role	% Time	Inter.
Wrist							
Light (≤3 METs)	4.31[1]	-0.05[2]	2.20	-0.03	0.28	0.07	0.67
Moderate (3-6 METs)	-0.27	0.06[2]	-0.62	0.04	0.86	0.03	0.63
Vigorous (>6 METs)	0.63	0.11[2]	1.23	-0.02	0.62	0.20	0.09
Hip							
Light (≤3 METs)	1.74[1]	-1.8E-3	1.44[1]	-0.01	0.71	0.36	0.56
Moderate (3-6 METs)	1.59[1]	1.4E-3	0.69	0.01	0.21	0.41	0.56
Vigorous (>6 METs)	1.49[1]	0.01	0.72	0.05	0.29	0.39	0.61

[1]Intercept statistically significantly different from 0.
[2]Slope statistically significantly different from 0.

The main effect of job role was statistically significant for moderate hip activity and (*p* = 0.01) and vigorous hip activity (*p* = 0.01) on their effect on physical exertion ratings (Table 11). The main effect of percent time spent in energy expenditure categories was statistically significant for the categories of light hip activity and moderate hip activity. Physical exertion ratings increased by 0.01 units per 10% time spent in moderate hip activity (*p* = 0.04). The interaction between job role and percent time was not statistically significant for any level of wrist or hip activity.

Table 11. Percent time spent in energy expenditure levels and its effect on self-reported physical exertion by job role and sensor location.

	Servers (n=8)		Cooks (n=5)		*p*-value		
Energy Expenditure	Intercept	Slope	Intercept	Slope	Job Role	% Time	Inter.
Wrist							
Light (≤3 METs)	0.37	2.4E-3	1.44	-4.7E3	0.40	0.93	0.79
Moderate (3-6 METs)	0.89[1]	-0.01	1.13	2.5E-3	0.83	0.72	0.59
Vigorous (>6 METs)	0.26	0.03	1.12	0.01	0.20	0.42	0.64
Hip							
Light (≤3 METs)	1.03[1]	-0.01[2]	1.36[1]	-2.4E-3	0.37	0.03	0.19
Moderate (3-6 METs)	0.20	0.01[2]	1.12[1]	2.8E-3	0.01	0.04	0.27
Vigorous (>6 METs)	0.09	0.04[2]	1.28[1]	-0.01	0.01	0.56	0.34

[1]Intercept statistically significantly different from 0.
[2]Slope statistically significantly different from 0.

The main effect of job role was not statistically significant for any level of activity and their effect on physical discomfort ratings (Table 12). Although not statistically significant, cooks appeared to exhibit greater physical discomfort during time spent in vigorous hip activity (*p* = 0.09). The main effect of percent time spent in energy expenditure categories was statistically significant for the categories of light wrist activity (*p* = 0.02) and moderate wrist activity (*p* = 0.03). Cooks experienced a decrease in physical discomfort by 0.09 units per 10% time spent in light wrist activity. The interaction between job role and percent time was not statistically significant for any level of wrist or hip activity.

Table 12. Percent time spent in energy expenditure levels its effect on self-reported physical discomfort by job role and sensor location.

	Servers (n=8)		Cooks (n=5)		*p*-value		
Energy Expenditure	Intercept	Slope	Intercept	Slope	Job Role	% Time	Inter.
Wrist							
Light (≤3 METs)	2.16[1]	-0.02	6.12[1]	-0.09[2]	0.09	0.02	0.12
Moderate (3-6 METs)	0.35	0.03	-2.43	0.11	0.32	0.03	0.16
Vigorous (>6 METs)	0.84	0.04	0.45	0.12	0.80	0.10	0.34
Hip							
Light (≤3 METs)	1.19[1]	-8.9E-4	2.39[1]	-1.0E-4	0.27	0.90	0.99
Moderate (3-6 METs)	1.12[1]	6.7E-4	2.23[1]	2.6E-3	0.25	0.83	0.90
Vigorous (>6 METs)	1.04[1]	0.01	2.57[1]	-0.04	0.09	0.68	0.53

[1]Intercept statistically significantly different from 0.
[2]Slope statistically significantly different from 0.

The main effect of job role was not statistically significant for any level of activity and their effect on lack of energy. The main effect of percent time spent in energy expenditure categories was statistically significant for the categories of light wrist activity and moderate wrist activity (Table 13). Both servers and cooks experienced a decrease in lack of energy as percent time spent in light wrist activity increased. Servers had a decrease of 0.03 units per 10% time spent during shift while cooks had a decrease in 0.10 units per 10% time spent in this category (p = <0.01). Cooks (slope: 0.12 per 10% time spent in shift) more than doubled servers (slope: 0.05 per 10% time spent in shift) in self-reported lack of energy as percent time spent in moderate wrist activity increased (p = < 0.01). The interaction between job role and percent time was not statistically significant for any level of wrist or hip activity.

Table 13. Percent time spent in energy expenditure levels and its effect on self-reported lack of energy by job role and sensor location.

	Servers (n=8)		Cooks (n=5)		*p*-value		
Energy Expenditure	Intercept	Slope	Intercept	Slope	Job Role	% Time	Inter.
Wrist							
Light (≤3 METs)	4.10[1]	-0.03[2]	6.65[1]	-0.10[2]	0.27	<0.01	0.13
Moderate (3-6 METs)	0.67	0.05[2]	-2.83	0.12[2]	0.17	<0.01	0.22
Vigorous (>6 METs)	1.62[1]	0.06	0.78	0.10	0.60	0.12	0.75
Hip							
Light (≤3 METs)	2.48[1]	-0.01	2.76[1]	-0.01	0.78	0.25	0.72
Moderate (3-6 METs)	1.97[1]	0.01	1.77[1]	0.01	0.81	0.28	0.78
Vigorous (>6 METs)	2.05[1]	0.01	1.85[1]	0.06	0.80	0.42	0.57

[1]Intercept statistically significantly different from 0.
[2]Slope statistically significantly different from 0.

2.4. Discussion

This study allowed an assessment of whether self-reported fatigue was affected by working in the front or back of the house and whether self-reported physical activity differed between these work groups over work shifts. When looking at the SOFI questionnaires by themselves, job role did not have a significant effect on self-reported fatigue subscales. In contrast, time since the start of the shift (regardless of job role) did significantly affect all five SOFI subscales. There was statistical significance of the interaction between job role and time for sleepiness, physical exertion, and lack of motivation. This suggests that self-reported sleepiness, physical exertion, and lack of motivation ratings during a shift depends on job role. Servers appeared to spend most of their shift in light wrist activity while cooks see a more even distribution between light and moderate wrist activity with double the amount of vigorous wrist activity. Servers did spend more of their shift in vigorous hip activity than cooks, which is to be expected as servers at this restaurant cover more surface area to perform their required tasks. Cooks' job tasks require more use of the upper body compared to the lower body. A task of a cook on any given night could be to make pizzas at the end of the line; this task has the cook stand in the corner not moving their lower body as much compared to the movement of their upper body (for this specific restaurant). For Tables 9-13, the goal was to examine any relationships between percent time spent in levels of physical activity and their effects on fatigue ratings for both job roles. It was observed that SOFI ratings were not affected by job role or percent time.

There are multiple limitations to this research study. The SARS-CoV-2 pandemic affected many restaurants and restaurant staff, especially in the state of Michigan where rules and regulations pertaining to SARS-CoV-2 were some of the strictest in the country. At the time of data collection, restaurants were only allowed to operate at half capacity. Data collection was performed in mid-March to early April, so many days the weather did not allow for more seats to open outside where state laws allowed outdoor dining. Other limitations to this study include the small number of participants (n=13) and the observation of only three work shifts.

For this study, only two independent variables were examined as risk factors for fatigue in restaurant staff. However, there are numerous other factors that can affect a worker's fatigue levels during a shift that were not measured for. Workers may use restaurant work as a secondary source of income, so workers may have worked another job earlier in the day before a shift, or another job the night before while opening the restaurant which can affect fatigue. To cope with this, caffeine might be used to fight any fatigue before and during a shift. Mental health can also play a factor into fatigue levels as depression and anxiety are associated with motivation levels. Psychosocial factors also affect fatigue levels. Factors in the work setting such as who is on staff that day and the relationships between those staff members, the presence of a manager, and the strength and abilities of the other staff can all affect workload and fatigue levels.

One final limitation is the assumption of the statistical independence of serves and cooks. For purposes of this research, job roles were viewed as independent of one another; this is not always true. The entire restaurant is viewed as one system, and job roles can affect one another. If a server inputs items wrong and must change an order while the kitchen is already working on it, or servers forget about submitting an order and load the kitchen with multiple orders, this is adversely affecting the kitchen. On the contrary, if a cook messes up a food order and remakes the food item delaying delivery to a table, this adversely affects the server.

2.5. Conclusion

Both job roles affected self-reported fatigue and some levels of physical activity, but job roles generally did not affect physical activity levels and their effect on self-reported fatigue. Percent of shift in different levels of physical activity does vary between servers and cooks, especially for wrist activity and vigorous hip activity. From this small sample size (n=13), there was not an observed difference that appeared between self-reported fatigue of servers and cooks throughout a work shift. Sleepiness was affected the most by job role and time spent at the restaurant. When focusing on a specific intensity level of physical activity, intensity levels showed no indications for its effect for any of the reported SOFI subscales across a shift between the two job roles.

The Actigraph GT9X Link and SOFI questionnaires were useful and effective for capturing real-time physical activity data and self-reported measures of fatigue. These tools can be used in a workplace to provide a measure as to what workers experience in a typical shift which may lead to new and improved design of work. If anything, it allows the business to understand what its workers experience throughout the course of a shift and can provide valuable information to a manager to be utilized for purposes such as scheduling.

CHAPTER THREE: CONCLUSION

The aim of this study was to use both objective and self-report methods to study fatigue between two job roles at a restaurant. Self-reported fatigue was measured using the Swedish Occupational Fatigue Inventory (SOFI) and used to observe if a server or cooks' job role had an effect on their perceived fatigue. Servers and cooks were also studied to determine if self-reported fatigue ratings were affected by percent time spent in levels of wrist and hip physical activity using the Actigraph GT9X Link. The SOFI proved to be a viable option to assess self-reported fatigue in the restaurant setting. It was quick to use and limited interference in a worker's normal workflow while capturing important feelings of the workers. Self-reported fatigue did change throughout the course of a shift, indicating that work factors of the restaurant had an effect on perceived fatigue for the workers. Job role also had an effect on perceived fatigue during a shift, however, differences between the two job roles were not concluded. The inertial measurement unit (IMU) within the Actigraph GT9X Link was able to capture physical activity data and could be used as a method for data collection in the restaurant setting as well. Levels of physical activity can be useful in understanding the physical demands of an occupation and can be easily presented to an audience if needed.

One goal of this study was to use both methods together to get a better measurement of fatigue across a shift as a workers' fatigue can be experienced cognitively and physically. However, there were not many significant findings when analyzing each SOFI factor separately with percent time spent in each level of physical activity for both sensor locations. When analyzing SOFI factors using total wrist and hip activity across an entire shift, sleepiness and lack of motivation showed the most promise to being predictable temporally through total MET counts. However, the small sample size of 13 workers may have had an affect on the model, and more observations may be needed in the future to test the relationship between physical activity and self-reported measures of fatigue. Future work may expand on this and focus on the increase in total physical activity bouts throughout a shift and its relation to cognitive fatigue.

Eventually, it will be incredibly useful to use accurate measurement methods to measure both physical and cognitive fatigue at the same time to better estimate fatigue. These methods can be used across many occupations but studying the restaurant industry is essential as it is a fascinating element to the economy and lifestyle of many people around the world. Results of studies like this one can further contribute to the understanding of restaurant work demands and lead to the mitigation of any risk factors through proper management. Feedback from a study like this can provide the restaurant recommendations for shift scheduling and can show the busiest periods of the restaurant and when the restaurant is most at risk to errors. Future studies can use customer satisfaction questionnaires that can be given to the managers as an overall performance metric of the restaurant experience. Customer satisfaction surveys can be viewed with other information such as total sales in one day to compare satisfaction between busy and non-busy days. The main objective is to identify not only what is making the restaurant money, but what is losing the restaurant money.

As a student who has worked in the restaurant industry to help put himself through college for the last six years, this study was exciting for me. This study was also the first time I was able to perform data collection in the field. I was away from my advisor in another state, basically on my own for data collection which was frightening and exciting at the same time. I had fun with the process and learned lessons I hope to use for the next time I find myself in a similar situation. I learned that data collection takes time, and not everything is going to go the way it was designed to go. There are going to be things that cannot be controlled, and I will have to learn to adapt. I enjoyed being able to take the techniques and information taught in the classroom these past two years and put it to use in the field, especially when there were no guarantees due to the pandemic. I feel fortunate I had this opportunity and I hope my research is able to contribute to the understanding of fatigue and the work demands of the restaurant industry.

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