AN ASSESSMENT OF BILATERAL SHOULDER RANGE OF MOTION IN FIREFIGHTER TRAINEES

By

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AN ASSESSMENT OF BILATERAL SHOULDER

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TRAINEES

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Abstract: Firefighting is innately a dangerous profession. Many essential tasks that firefighters must perform involve repetitive overhead motions, which can place stress on the shoulder joint. Unpredictable environments paired with potentially biomechanically compromising movements of the shoulder put this population at an increased risk of injury. The purpose of this study was to assess bilateral shoulder range of motion (ROM) of firefighter trainees. Retrospective data for 30 male firefighter trainees (age 28.4 ± 5.47 yrs.; height 175.18 ± 33.48 cm; weight 86.4 ± 10.92 kg) were analyzed. Data included demographic (age), anthropometrics (height and weight), and select movement pattern (shoulder abduction, shoulder horizontal abduction, shoulder external rotation, shoulder internal rotation, shoulder flexion, and shoulder extension) range of motion information. Firefighter trainees' range of motion measures differed significantly from normative data, especially shoulder external rotation, which yielded the least amount of trainees within normal range and the most trainees below normal range. The firefighter trainees' tendency to differ from normal range of motion suggests that this population could benefit from a movement assessment in order to identify those individuals with a potentially increased risk of injury.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

CHAPTER I

INTRODUCTION

1.1 Introduction

The shoulder, or glenohumeral joint, is a complicated and dynamic structure comprised of bones, articulations, ligaments, and several intrinsic and extrinsic muscles. The main movements of the joint are flexion, extension, abduction, adduction, internal rotation, and external rotation. The nature of the joint allows for "the greatest range of motion of any joint in the body" (Terry & Chopp, 2000). This range of motion (ROM), while pertinent to athletes and professionals alike, also increases the risk of injury to the joint (Terry & Chopp, 2000). This increase in risk paired with occupational hazards has the potential to cause even greater risk of injury among firefighters, which, in turn, could result in missed work, medical costs, and long-term adverse health conditions.

The profession of firefighting is physically demanding and inherently dangerous with the exposure to live fires and rescues in unpredictable environments. Essential job tasks include activities such as lifting, pulling, advancing, and dragging (Elsner & Kolkhorst, 2008). Based on the physicality of these tasks, firefighters are at an increased risk of injury. The National Fire Protection Association© (NFPA©) reported that 50% of all injuries sustained by United States firefighters were placed in the sprain, strain, or muscular pain category and "accounted for 56% of all non- fireground injuries", which includes training (Campbell & Evarts, 2020). Furthermore, according to Nazari et al. (2020), 23% of musculoskeletal disorders in Canadian firefighters were related to shoulder pain. With shoulder injuries accounting for such a large amount of the musculoskeletal injuries in the firefighting population, and with musculoskeletal injuries being one of the primary outcomes of injury, there is a need to mitigate injury to this area.

One method of injury reduction that has received interest is the assessment of mobility and screening for movement discrepancies (Pozzi et al., 2020). ROM is commonly used as an assessment of joint mobility (Soucie et al., 2011). There are many tools that can be utilized to measure ROM, most notably including goniometry and motion capture technology. Hayes et al. (2001) found the inter-rater and intra-rater reliability of goniometry to both be fair-good. Markerless motion capture has been studied significantly less than other modes of assessing ROM, however, Schmitz et al. (2014) were able to "accurately (2°) and reliably (1.1°) calculate joint angles" of the lower extremity using a single camera markerless motion capture system. This suggests that markerless motion capture systems may efficiently be used to assess ROM.

1.2 Purpose of the Study

The purpose of the present study was to assess bilateral shoulder ROM of firefighter trainees. Possible predisposing conditions paired with hazardous work environments, compromised positions, and strenuous tasks performed makes this group an ideal population to evaluate prior to their career in firefighting to reduce the long-term risk of shoulder injuries. Knowledge of deficiencies beforehand has the potential to mitigate risk of injury and identify those individuals that could be at increased risk.

1.3 Research Question

The following research question guided this study:

1. Do firefighter trainees' shoulder range of motion (ROM) significantly differ from normative data?

1.4 Hypothesis

1. Firefighter trainees' shoulder range of motion (ROM) will significantly differ from normative data.

CHAPTER II

REVIEW OF LITERATURE

This literature review will focus on the anatomy of the shoulder complex, injury prevalence in firefighters, fire academies, movement screenings, measuring shoulder ROM, and the DARI motion capture system.

2.1 Anatomy of the Shoulder

Movement of the shoulder complex is the primary focus of the present study. The shoulder, also known as the glenohumeral joint, is a ball-and-socket joint that is comprised of an intricate arrangement of bones, ligaments, and muscles. The functional anatomy of the shoulder has been comprehensively researched (Terry & Chopp, 2000, Lintner et al., 2008; Namdari et al., 2012; Bakhsh & Nicandri, 2018). The function of the shoulder, and therefore its potential dysfunction, is determined by its extensive network of articulations, structures, and anatomical relationships (Bakhsh & Nicandri, 2018). This joint normally allows for 170° to 180° of flexion, 50° to 60° of extension, 170° to 180° of abduction, 90° to 100° of external rotation, and 80° to 90° of internal rotation (Starkey & Brown, 2015). Without proper ROM, efficient biomechanics cannot be maintained (Starkey & Brown, 2015).

2.2 Injury Prevalence in Firefighters

According to the 2019 NFPA Survey of Fire Departments for US Fire Experience, 50%

of all firefighter injuries were classified as strain, sprain, or muscular pain and another 3% of all firefighter injuries were classified as dislocation or fracture (Campbell & Evarts, 2020). The survey also reported injuries by type of duty. Musculoskeletal injuries (sprain, strain, muscular pain, dislocation, fracture) accounted for 61% of injuries responding to or returning from incidents, 44% of fireground injuries, 56% of injuries at a non-fire emergency, 66% of training injuries, and 57% of injuries occurring during other duties (Campbell & Evarts, 2020). In total, 32,200 of 60,825 injuries sustained by firefighters in 2019 were musculoskeletal in nature (Campbell & Evarts, 2020).

Nazari et al., (2020) investigated the prevalence of musculoskeletal disorders among Canadian firefighters, where shoulder injuries accounted for 23% of reported injuries. In 2019, Orr et al. sought to create a profile of injuries sustained by firefighters and reported that 14.5% of musculoskeletal injuries were to the shoulder. These high percentages are most likely due to the unstable nature of the shoulder complex which causes predisposition to overuse conditions, "especially in individuals participating in activities that require repeated overhead movements" (Starkey & Brown, 2015, p. 601) and many essential job tasks that firefighters routinely perform involve the shoulder and repetitive overhead motions (Elsner & Kolkhorst, 2008).

2.2.1 PPE Effect on Shoulder Range of Motion

The full personal protective equipment (PPE) that firefighters don on the job can impact mobility and function (Ciesielska-Wróbel et al., 2017). PPE consists of an insulated coat and pants, waterproof boots, hood, helmet with a face shield, gloves, and a self-contained breathing apparatus (SCBA). In the 2017 study by Ciesielska-Wróbel et al., it was found that different types of firefighter turnout produced different limitations in ROM in different joints. Five shoulder movements were measured, including abduction, horizontal flexion, horizontal extension, vertical flexion, and vertical extension (Ciesielska-Wróbel et al., 2017). Statistically significant differences were found for shoulder abduction, horizontal extension, and vertical extension between the subjects' reference outfit (t-shirt and shorts) and a bulky PPE uniform (coat and pants) (Ciesielska-Wróbel et al., 2017). Differences in shoulder abduction in the subjects' reference outfit and the traditional PPE coat and pants were also statistically significant (Ciesielska-Wróbel et al., 2017). Restriction of a firefighter's ROM could put them in biomechanically compromising positions, thereby increasing their risk of injury.

2.2.2 Financial Toll of Firefighter Injuries

A 2016 study by Frost et al. of a large Canadian fire department reported that "combined medical and compensation cost of injuries in 2012 was $555,955, of which 77% was for [musculoskeletal disorders]" (p. 499). They went on further to say that shoulder injuries equated to $76,838 of the total cost of injuries (Frost et al., 2016). Butry et al. and the National Institute of Standards and Technology (2019) estimated the annual cost of firefighter injuries in the United States to be "between $1.6 billion and $5.9 billion" (p. 25). There is further financial burden when considering time lost to injury (Butry et al., 2019). Individuals sustaining injury could be restricted duty or completely off duty because of an injury which creates staffing challenges for a department. With injuries equating to a billion-dollar industry within this population, implementing some means of injury prevention across the entire population could be beneficial and potentially effective at reducing injury related costs.

2.3 Fire Academies

Firefighter recruits often attend a fire academy to be properly trained and receive necessary education, (Lan et al., 2021). The instruction at these academies focuses on the physical fitness and preparedness of trainees to complete key firefighting tasks (Hollerbach et al., 2019). The U.S. Fire Service, along with the joint efforts of the International Association of Fire Fighters and the International Association of Fire Chiefs have put out several documents detailing health and fitness programs for U.S. and International Fire Departments alike (Cornell et al., 2017; Fourth Needs Assessment of the U.S. Fire Service, 2016; The Fire Service Joint Labor Management Wellness-Fitness Initiative, 2018). However, while at the fire academy, trainees are still subject to similar hazards and situations as full-time firefighters (Lan et al., 2021). This increase in assumed risk paired with the novice and inexperienced nature of trainees puts them at a potentially increased risk of injury. Le et al. (2020) suggests that larger fire organizations "may be better suited to mitigate and manage musculoskeletal disorders" due to enhanced training and greater resources. This implies that larger academies may be an ideal setting to implement more advanced injury mitigation.

2.4 Movement Screenings

One possible solution for the mitigation and management of musculoskeletal injuries is to conduct movement screenings on those in the firefighter population, ideally before they begin their stint of service and specifically while attending a fire academy. Movement screenings seek to assess overall functional movement capacity of an individual which in turn can identify possible issues that each individual could face (Lisman et al., 2013). Identification of movement deficits by trained professionals, such as certified athletic trainers, should lead to appropriate intervention and, eventually, prevention of further complications and/or injury. One of the most common types of this movement assessment is the Functional Movement Screen (FMS). The FMS was designed to "identify functional movement deficits and asymmetries that may be predictive of general musculoskeletal conditions and injuries with an ultimate goal of being able to modify the identified movement deficits through individualized exercise prescription" (Teyhen et al., 2012, p. 531). Another option for movement screening is to measure the ROM of certain joints and compare them to normative data as orthopedic-type clinicians do during baseline and injury assessments (Starkey & Brown, 2015). Measuring ROM allows clinicians to not only compare values to a normal range, but also allows them to compare an individual's ROM bilaterally. This in turn provides the clinician with information to assess the individual for ROM deficiencies or discrepancies.

2.5 Measuring Shoulder Range of Motion

There are several ways to measure shoulder ROM. The simplest ROM assessment is visual estimation by an evaluator, which has fair-good reliability (inter-rater ICC = 0.57-0.70; intra-rater ICC = 0.59-0.67; $p < 0.05$) (Hayes et al., 2001). More commonly used, especially in clinical type settings and for research purposes, is goniometry. Goniometry traditionally involves the use of a plastic goniometer (also known as a universal goniometer) with two arms, a fulcrum, and a protractor (Starkey & Brown, 2015) and can be used with fair-good reliability (inter-rater ICC = 0.64-0.69; intra-rater ICC = 0.53-0.65; $p < 0.05$) (Hayes et al., 2001). Goniometers are utilized by placing the fulcrum over a joint with one arm stationary over a standard anatomical landmark and the other arm moving to align over another landmark so that the angle between the two arms are read as the ROM (Johnson et al., 2015). Electronic goniometers have more recently been utilized and have been found to have comparable reliability as universal goniometers (Johnson et al., 2015). These work similarly to traditional goniometers as they display an arrow indicating the starting direction of the first landmark and then are moved in the direction of the motion to the second set of landmarks to calculate the degrees between the two points (Johnson et al., 2015).

Digital inclinometers are another form of ROM measurement, which Kolber and Hanney (2012) found comparable to goniometric measures. These devices rely on constant gravity and the clinician’s ability to establish an accurate zero prior to the movement to measure the degrees of motion (Kolber & Hanney, 2012). Still photography for the purpose of ROM measurements rates similarly with fair-good reliability (inter-rater ICC = 0.62-0.73; intra-rater ICC = 0.56-0.61; $p < 0.05$) (Hayes et al., 2001). To utilize this technique, bony landmarks are marked prior to movement and then a photograph is taken at the end range of the movement performed (Hayes et al., 2001). The present study utilizes markerless motion capture system to measure shoulder ROM in the firefighter trainees. Schmitz et al. (2014) found that a single camera markerless motion capture system was able to "accurately (2°) and reliably (1.1°) calculate joint angles" of the lower extremity. Markerless motion capture systems create a biometric skeleton of a subject in order to measure ROM (Schmitz et al., 2014).

2.6 DARI Motion Capture System

The DARI motion capture system used in the present study has not been as extensively researched as other markerless motion capture systems. The literature that does exist, however, suggests high reliability in the evaluation of human movement. Martinez et al. (2018) compared DARI parameters for body motion evaluation to the Unified Parkinson's Disease Rating Scale (UPDRS) and found significant negative correlations for gait and stride length ($r = -0.833$, $p = 0.039$) in addition to right step length ($r = -0.926$, $p = 0.008$). This implies that the DARI motion evaluation correlated with UPDRS scores to determine those with Parkinson's disease (Martinez et al., 2018). More notably, Cabarkapa et al. (2019) specifically tested the DARI motion capture system and found excellent inter-device reliability with all intra-class correlation coefficients having high significance (ICC = 0.86–0.99) across the following five scores (arbitrary units): power, functional strength, dysfunction, composite (power + functional – dysfunction), and vulnerability. Although it has not been specifically tested for ROM reliability, the outcome of this study suggests that the DARI motion capture system could reliably assess overall body functional motor capabilities (Cabarkapa et al., 2019). Other markerless motion capture systems have been tested for reliability. The 360 Kinect® (Microsoft Corp., Redmond, WA, USA) motion-capture camera system, which suggested excellent intraclass correlation (Castro-Luna & Jiménez-Rodríguez, 2020). The pitfall of comparison between markerless motion capture systems, as pointed out by Castro-Luna & Jiménez-Rodríguez (2020), is the "the biomechanical patterns they use are different, and thus the results cannot be compared or discussed" (p.11).

The available literature provides evidence that the ROM of the shoulder complex should be considered when evaluating the health and wellness of firefighters. The high prevalence of musculoskeletal injury, specifically to the shoulder, warrants some type of movement screening to identify individuals who might be lacking ROM and therefore at increased risk of injury. Because fire academies are usually larger fire organizations, they may have the means to conduct these types of screenings, especially if trainees could be tested prior to any type of training and then routinely screened. The DARI motion capture system may be an excellent means to conduct these screenings with its markerless technology.

CHAPTER III

METHODOLOGY

The purpose of this study was to analyze archived data from a motion analysis performed on male firefighter trainees at a university in Colorado Springs, CO. This chapter will explain the details of the research study including the participants, research design, instrumentation, and procedures utilized for the motion analysis.

3.1 Participants

Archived data for a cohort of firefighter trainees from a Colorado Firefighter Training Academy were used for this analysis. This cohort consisted of 32 firefighter trainees (31 males and 1 female) that voluntarily agreed to allow their data from a movement screen performed within their agency to be used in this analysis. The female's data was not utilized in this particular study in order to minimize confounding variables. The remaining subjects' age range was from 21 to 39 years old (age 28.4 ± 5.47 yrs.; height 175.18 ± 33.48 cm; weight 86.4 ± 10.92 kg). This study will provide an opportunity to evaluate the motion analysis results to identify movement imbalances in the shoulder among cadet firefighters.

3.2 Research Design

A cross-section observational design was used for this study. The subjects were already part of a Colorado Firefighter Training Academy and participated in the motion analysis as part of a voluntary research study. Prior to data collection, this study was submitted to and approved by the university review board for human subjects. Informed written consent was also obtained by all participants prior to testing. Thus, pre-existing data will be utilized for this analysis.

3.3 Instrumentation/Testing

The Dynamic Athletic Research Institute (DARI) motion capture system (Motion Platform, version 3.2-Denali from Scientific Analytics Inc., Kansas City, KS, USA) was utilized to obtain data from the participants. This marker-less system utilizes 8 high-speed cameras (120 Hz) that are placed around the room and a computer-based analysis software. The motion analyses were performed in the fitness room at the fire agency in which the data was collected. Each participant completed 19 movements in the same order. For the purpose of the current study, we focused only on those movements pertaining to the shoulder. These were the first 4 movements of the analysis, and they were completed in the following order:

Shoulder Abduction: Trainees were instructed to start with their arms at to the sides and palms facing forward. While keeping their arms straight, the trainees were asked to raise the arms out from their sides and over the head (abduct), keeping the palms forward throughout the entire movement.

Shoulder Horizontal Abduction: Trainees were instructed to start with their arms out in front at shoulder height palms facing each other. The trainees were then asked to bring their arms away from each other and behind the body as far as possible, keeping the arms at shoulder height throughout.

Shoulder Internal/External Rotation: The trainees were instructed to start with their elbows and shoulders bent 90 degrees and palms facing down. The trainees were then asked to rotate their arms up and back as far as they could (external), and then forward and down as far as they could (internal). Trainees were instructed to keep their elbows in the same spot during the movement.

Shoulder Flexion/Extension: The trainees were instructed to begin with their arms at their side. In one fluid motion, the trainees were asked to bring their hands forward and up above the head, then down and back behind the body, and then return to the original position. During the movement, the trainees were instructed to keep their elbows locked and shoulders back.

3.4 Procedures

A motion analysis, consisting of each movement in the instrumentation section, was utilized to examine movement and bilateral differences among each participant. The trainee participants were required to wear their physical training attire during the motion analysis session. Participants self-reported height and weight. Prior to their battery of movements, each participant was instructed to stand in the middle of the room with their feet shoulder width apart and their arms outstretched to the side with elbows and wrists flexed so that the DARI Motion system could create a biometric skeleton of the participant. Each movement was measured in degrees at the terminal point of the movement and recorded in the DARI Motion system and exported as individual participant files. The participants' data was analyzed to determine bilateral imbalances in each subject. This data was then utilized to make comparisons among the group and make inferences based on this sample population. Subjects' data was evaluated using specialized biomechanical algorithmic software.

3.5 Statistical Analysis

Mean scores and standard deviations were calculated for each variable of the shoulder movements assessed. Descriptive statistic data is presented as group mean (±SD). Percentages of each movement compared to normative data as a range of degrees of ROM for each variable of the shoulder movements per Starkey and Brown (2015) were also assessed. Bilateral differences for each variable were reported as delta values. Paired-sample t-tests were conducted to compare right and left ROM values. Statistical analysis was completed using the Statistics Package for Social Sciences (Version 26.0; IBM Corporation, New York, NY, USA).

CHAPTER IV

RESULTS

4.1 Descriptive Statistics

From the males of the cohort of firefighter trainees, one participants' data was unrecoverable; therefore, thirty participants' movement data were considered for statistical analysis (age 28.4 ± 5.47; height 1.8 ± 0.05 m; weight 86.4 ± 10.92 kg). Dominant limb was not identified. Shoulder abduction, horizontal abduction, internal rotation, and shoulder flexion were measured as a maximum value at a positive degree while external rotation and extension were measured as a maximum value at a negative degree. Values for the left and right arm were measured and the bilateral difference was assessed as delta. Normative data was determined by ROM assessment parameters per Starkey and Brown (2015). A quality ROM value was determined if it was in the normative range for that shoulder movement. Normative shoulder ROM ranges are presented in Table 1. Average measures of shoulder ROM are presented in Table 2. P-values comparing right versus left are also reported in Table 2. Percentages for each movement compared to normative data ranges are presented in Table 3.

Table 1. Normative Shoulder ROM Ranges.

Abduction	170° to 180°
Horizontal Abduction	30° to 45°
External Rotation	-90° to -100°
Internal Rotation	80° to 90°
Flexion	170° to 180°
Extension	-50° to -60°

ROM: Range of Motion. Adapted from Starkey and Brown, 2015.

Table 2. Average Measures of Shoulder ROM in Firefighter Trainees.

	Left	**Right**	**Delta**	
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**P-Value**
Abduction	172.7 ± 8.8°	175.3 ± 9.2°	6.2 ± 4.7°	0.258
Horizontal Abduction	31.6 ± 9.9°	35.3 ± 8.9°	4.9 ± 3.0°	0.347
External Rotation	-80.8 ± 13.8°	-85.6 ± 14.8°	5.9 ± 4.2°	0.193
Internal Rotation	76.5 ± 19.3°	76.6 ± 19.8°	6.1 ± 4.4°	0.994
Flexion	171.1 ± 11.6°	172.4 ± 12.4°	3.4 ± 2.5°	0.690
Extension	-46.4 ± 13.5°	-48.8 ± 12.0°	6.5 ± 6.9°	0.477

ROM: Range of Motion, Delta: Bilateral Difference

Table 3. Percentage of Shoulder ROM Measures Compared to Normative Data.

		Left	Right
Abduction			
	> 180°	23.33%	30.00%
	170° to 180°*	36.67%	43.33%
	160° to 169.99°	36.67%	20.00%
	150° to 159.99°	0.00%	6.67%
	< 150°	3.33%	0.00%
Horizontal Abduction			
	> 45°	6.67%	10.00%
	30° to 45°*	50.00%	66.67%
	20° to 29.99°	40.00%	16.67%
	< 20°	3.33%	3.33%
External Rotation			
	> -100°	10.00%	16.67%
	-90° to -100°*	6.67%	16.67%
	-80° to -89.99°	33.33%	33.33%
	-70° to -79.99°	30.00%	23.33%
	< -70°	20.00%	10.00%
Internal Rotation			
	>90°	30.00%	26.67%
	80° to 90°*	16.67%	20.00%
	70° to 79.99°	13.33%	20.00%
	60° to 69.99°	20.00%	20.00%
	< 60°	20.00%	13.33%
Flexion			
	> 180°	23.33%	30.00%
	170° to 180°*	36.67%	33.33%
	160° to 169.99°	20.00%	20.00%
	150° to 159.99°	13.33%	10.00%
	< 150°	6.67%	6.67%
Extension			
	> - 60°	13.33%	20.00%
	-50° to -60°*	26.67%	30.00%
	-40° to -49.99°	33.33%	23.33%
	-30° to -39.99°	16.67%	23.33%
	< - 30°	10.00%	3.33%

*Denotes normative range

CHAPTER V

DISCUSSION

5.1 Discussion

The purpose of this research project was to assess bilateral shoulder ROM of firefighter trainees. The shoulder, while allowing for extensive ROM, has an inherently established increased risk of injury (Terry & Chopp, 2000). The essential tasks of firefighters require repetitive shoulder movements, often overhead (Elsner & Kolkhorst, 2008). These tasks paired with hazardous and unpredictable environments have the potential to increase risk of injury in this already occupationally dangerous population. For this reason, injury mitigation and prevention are of top priority. One way to potentially prevent injury is to conduct movement screenings to identify dysfunctions. Identifying movement discrepancies and those at possibly increased risk prior to injury could lead to injury prevention.

The results of this study suggest that a majority of firefighter trainees' shoulder ROM differ from normative data. Horizontal abduction yielded the highest frequency of normal ROM among participants (left – 50.00%, right – 66.67%), while external rotation yielded the lowest frequency (left – 6.67%, right – 16.67%). External rotation, in turn, had the greatest number of trainees measure below normal ROM (left – 83.3%, right – 66.67%). Internal rotation had the greatest number of trainees measure above normal ROM (left – 30.00%, right – 26.67%). Delta values were relatively similar across all shoulder movements, meaning that the differences bilaterally for each movement were comparatively the same. This was further confirmed when no statistical significance was found when comparing right versus left range of motion values for each shoulder movement.

Having excessive ROM implies that a joint is hypermobile, or more mobile than normal (Simmonds & Keer, 2007). A limited, or decreased, ROM suggests that a joint may be hypomobile, or less mobile than normal (Davies & Ellenbecker, 1999). While an above normal ROM sounds like it could be beneficial, it actually suggests that that particular joint may be more unstable than it should be and/or prone to debilitating injury (Simmonds & Keer, 2007). Instability, especially in the shoulder, can put that joint at an increased risk of injury should it have to take on an excessive load, as firefighters often have to do (Simmonds & Keer, 2007). A lack of mobility implies that an individual will have to compensate elsewhere in order to perform a particular movement (Davies & Ellenbecker, 1999). For example, a decreased ROM in shoulder could negatively affect the load and movement of the elbow, hand, wrist, spine, or even lower extremity joints such as the hip or knee, depending on the load that is needing to be supported. This biomechanical compensation in other joints or areas of the body creates a predisposition and increased risk of injury and/or pain (Davies & Ellenbecker, 1999). Because of this study's cross-sectional design there is no way to know if the observed ROM discrepancies were present prior to the trainees' careers or if they are a result of the job. Future research should seek to study firefighters' ROM longitudinally in order to make this differentiation. Additionally, the findings of the present study highlight the need for a shoulder rehabilitation or pre-rehabilitation (rehabilitation prior to injury) program that includes stretching and/or strengthening to remedy these deficits and thereby improve ROM and/or shoulder strength and mitigate injury and instability.

Firefighters must routinely perform overheard movements, and more often than not, must do so with some type of load, whether that be equipment, tools, or even humans. Michaelides et al. (2011) investigated physical fitness as it pertains to a firefighter's ability to complete job tasks. The equipment used for this study included 9.53 kg, 15.24 m long and 7 cm wide hoses, a 4.1 kg sledgehammer, and an 82 kg mannequin (Michaelides et al., 2011). Furthermore, when a hose is charged, or filled with water, even more weight is needing to be supported. So, if a firefighter were to be attempting these tasks with diminished or increased ROM and added stress from equipment, the efficiency of the movements would decrease and put these individuals at an increased risk of injury.

5.2 Limitations

While there have been multiple studies including the use of markerless motion capture systems (Schmitz et al., 2014; Martinez et al, 2018; Cabarkapa et al., 2019, Castro-Luna & Jiménez-Rodríguez, 2020), there is limited research to suggest the true reliability of the DARI motion capture system regarding measures of ROM. Furthermore, the primary investigator of this study was limited in their understanding of the study since they were not present during data collection and acted solely as an interpreter and vehicle to report the data. The movements performed during the movement screening were done in the same order by each trainee. Therefore, this study was limited by its lack of randomization. This study was also limited in its ability to make predictions longitudinally as the data was pulled from a cross-sectional assessment. A longitudinal study would allow assessment of whether firefighter trainees were able to improve their mobility, maintain their proficient movement, or ultimately lose ROM during their stint at the fire academy. Moreover, analyzing the recruits as they progress in their careers to see the effects of an occupation in firefighting on ROM over time would also be of interest. Further research focusing on the firefighting trainee population to assess their ROM would further contribute to the findings of the present study and the current literature.

5.3 Conclusion

The present study sought to illuminate the issue of injury risk of firefighter trainees and a possible solution to mitigate this risk. While the number of individuals who do have ROM deficits may potentially be small and is hard to predict, a movement screening of some type is still warranted to detect those with issues prior to service. Even assessing those that do not have deficits at the beginning of their careers would be beneficial, especially if they were routinely screened to track ROM across their careers. While bilateral discrepancies were not found in the present study, the hypothesis that firefighter trainees' shoulder range of motion (ROM) would differ from normative data was confirmed. The trainees overall exhibited less ROM than normal. The significance of this study is found in the clinical implications. Firefighters are more 'overhead activity dominant' than most seem to realize, and the essential tasks of the job paired with observed differences from normal ROM values make them an ideal population to conduct movement assessments in order to identify individuals at higher risk of injury. It would stand to reason that firefighters would logically benefit from shoulder rehabilitation or pre-rehabilitation to address these ROM deficiencies in order to get them closer to a normal ROM.

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