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*Original Research*

# The Relationship Between Physical Mobility and Firefighter Occupational Task Performance

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ABSTRACT

***International Journal of Exercise Science 16(3): 1216-1227, 2023.*** Firefighters work in a dangerous profession with high injury rates. Mobility dysfunction in firefighters may impact performance and contribute to injury. The Functional Movement Screen (FMS) is commonly used to evaluate individuals for mobility dysfunction and compensatory movements. The purpose of this study was to identify if mobility is related to firefighters' occupational task performance. This was a retrospective study assessing 29 career firefighters using FMS and occupational performance task scores. Statistical analyses consisted of a multiple linear regression assessing predictors on occupational task performance, and 21 point-biserial correlations ran to assess the relationship between each individual predictor and occupational task performance. Of the 21 point-biserial correlations, four were found to be significant, indicating a relationship between the FMS and occupational task performance. Inline Lunge L had a negative correlation with occupational task time and was statistically significant ($r_{pb} = -0.46$, $p = 0.012$); Inline Lunge R had a negative correlation of moderate strength ($r_{pb} = -0.583$, $p = 0.001$), Inline Lunge Combined had a negative correlation of moderate strength ($r_{pb} = -0.523$, $p = 0.004$), and Shoulder Mobility L had a negative correlation of moderate strength ($r_{pb} = -0.445$, $p = 0.016$). This study determined that the Inline Lunge component of the FMS may be a key element in occupational task performance.

KEY WORDS: Tactical athlete, functional movement screen, fire service

## INTRODUCTION

Firefighters are known for working in an intense, chaotic, and dangerous profession (8). They protect the public while enduring challenging physical tasks, toxic fumes, and combating fires of varying magnitudes (13). In addition to fighting fires, they are the first responders in rescues and emergency medical calls (25). Firefighting is physically demanding, relying heavily on a firefighter's ability to maintain their physical activity capabilities. Common firefighting tasks include stair climbs, forcible entry into buildings and vehicles, body carry, and treating the injured (25, 27). Firefighters also work under an urgent timeframe, with limited visibility, and often in dangerous situations like collapsing floors with exposure to flame and smoke (25, 27). Additionally, firefighters' tasks are performed while wearing standard firefighting protective gear, which adds approximately 45 pounds of weight, considerably restricting their range of motion and overall mobility while on the job (27). Approximately 65,000 firefighters are injured annually due to these dangerous work conditions, which takes a toll on their bodies (3).

Firefighting requires aerobic and anaerobic conditioning to maintain continuous work on the fire scene, muscular endurance and strength to lift and carry tools or victims, and mobility for all occupation tasks (25). Mobility is specifically essential for lowering to pick-up equipment such as chainsaws, maintaining a half-kneeling hose suppression, or crawling on the ground for victim searches. Firefighters need to maintain an appropriate amount of mobility in their bodies to safely complete these occupational tasks. Furthermore, when firefighters are exposed to dangerous tasks in less-than-ideal situations, it further challenges their physical and mental fitness and potentially hinders their work (14). Mobility restrictions created by firefighters' personal protective equipment (PPE) have been shown to limit their ability to function and increase their risk of slipping, tripping, and falling (23, 28). Although firefighters train in gear to become accustomed to the lack of mobility and ensure proper task performance, research has found that the self-contained breathing apparatus (SCBA) gear specifically hinders firefighters' upper trunk and neck movement and that firefighting boots obstruct ankle mobility (23).

The purpose of this study was to better understand the relationship between firefighters' measured mobility and their performance on occupational tasks. The Functional Movement Screen (FMS) is a mobility tool that is used to screen individuals in a dynamic and functional capacity, more specifically in muscular and flexibility imbalances, for injury and performance predictability (6, 12). There are seven movements that are part of the screen that requires a combination of stability and mobility in movement patterns (6, 11), allowing the tester to evaluate asymmetries, compensations, and overall functional mobility deficits (12). The movement screen is typically performed prior to sport competitions (6), but it has also been used in varying athletic populations to evaluate the risk of injury. Studies have found that individuals with a total score of ≤ 14 out of 21 possible points are at a greater risk of injury (7, 12, 15, 17, 22). These studies have been implemented in settings such as law enforcement, collegiate athletes, and the military in order to investigate the FMS and its ability to identify those who are predisposed to injury or in research that have found correlations between the FMS assessing mobility and occupational tasks (1, 7). However, there is limited work investigating the impact of mobility on occupational task performance related to fire service (19). Firefighters' occupational role in dangerous situations should not be taken lightly, and it would be helpful to assess their hindrance in mobility, whether it be from the gear or lack of controlled functional movements (23, 28).

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## METHODS

*Participants*

Twenty-nine career firefighters from rural southeast Georgia volunteered to participate in the study. A convenience sample was utilized, and the subjects were contacted with the permission of the deputy chief, and they were informed of the benefits, risks, and purpose of the study. To be eligible for participation, individuals had to be a full-time active-duty firefighter in the department and older than 18 years. Exclusion criteria entailed any musculoskeletal injuries that prevented normal job function within the previous six months. Participants then consented to use their existing data that was deidentified from their personal information. All methodologies used in the study were approved by the university's institutional review board, approval number H19098.

*Protocol*

For this study, coded data were extracted from existing occupational training and physical testing measures. The data were pulled from the department's March 2020 fitness assessment testing date. Occupational task performance time was pulled from an in-service training session in June 2020. The sample fire department follows the National Fire Protection Association's guidelines 1583 (21) for annual fitness assessments, with the addition of a supplemental movement screen. Data were extracted by a participant code, and no identifying information was provided to the researchers.

Occupational Task Performance Test: As part of the routine fire ground training, the firefighters completed seven tasks that simulated 15 minutes of on-scene fire duties (Table 1). A team of commanding training officers designed the seven-task course with standard measures and equipment for content validity and reliability (21). Total time to complete, average heart rate, and highest heart rate were recorded. Firefighters were fitted with a Polar H10 Heart Rate Sensor (Kempele, Finland), and heart rate was monitored for the entirety of the task with the Polar Beat smartphone application. Medical professionals were present each day for the simulation.

FMS: During the 2020 annual physical assessments, certified FMS professionals performed the measurements.

*Statistical Analysis*

All data were analyzed using SPSS Version 25.0 (IBM Corp., Armonk, NY). Each variable is presented as mean ± *SD* for each condition. Multiple linear regression analysis was utilized to answer research questions one and two. For question one, the independent variables were total FMS score, age, body mass index (BMI), and max heart rate, categorized as continuous variables. For question two, the independent variables were asymmetries, BMI, and age, and these are also all continuous variables. The predetermined cutoff for determining significance was set to $a = 0.05$; G*Power was used to run a sensitivity power analysis given the set sample size (with a total of 5 different predictor variables) while assuming an acceptable level of power ($P = 0.80$)

in order to identify a minimal detectable effect size for this study, $f^2 = 0.56$ (10). Lastly, the third research question was analyzed using point-biserial correlation, with all the elements being continuous. All the individual FMS elements, including the left and right sides, were analyzed individually, and a total combined score for each element was included in this analysis. For all three research questions, the dependent variable was continuous and labeled as occupational task time recorded in seconds. All data were analyzed retrospectively.

**Table 1.** Occupational task.

| Station | Occupational Task | Description |
|---|---|---|
| **0** | Simulated Fire Attack | Firefighters were instructed to treat the simulated fire attack as a real fire. Firefighters HRs were measured during the attack. |
| **1** | Quick Dress | Firefighters dressing as quickly as possible in full bunker gear. Dressing included boots, hood, pants, jacket, mask, helmet, a (SCBA) air pack, and gloves. |
| **2** | Forcible Entry | Firefighters were instructed to pick up the Halligan tool and force open the secured door. Once the door was opened firefighters were instructed to clip in the SCBA regulator, high rise hose pack, and walk through the door. |
| **3** | Stair Climb | Firefighters ascend 3 flights of stairs to the fourth floor while carrying high rise pack and Halligan tool. After reaching the top they descend the stairs to the bottom floor where they dropped the gear. |
| **4** | Fire Attack | Firefighters started at a fire hydrant and did 3 hose stretches with patterns: O, T, and Z. After completing each attack firefighters were instructed to return and touch the starting hydrant. They finished the attack with a full hose carry. |
| **5** | Crawl to Body Dummy Carry | Firefighters performed a quadrupled crawl 15.2m and then carried a body dummy(75kg) 15.2m. |
| **6** | Farmers Carry | Firefighters carried 2 24kg kettlebells 22.9m to a cone. |
| **7** | Ladder Raise | Firefighters carried a ladder 15.2m and then raised it against a shipping container. |

** Abbreviations: SCBA- Scott self-contained breathing apparatus

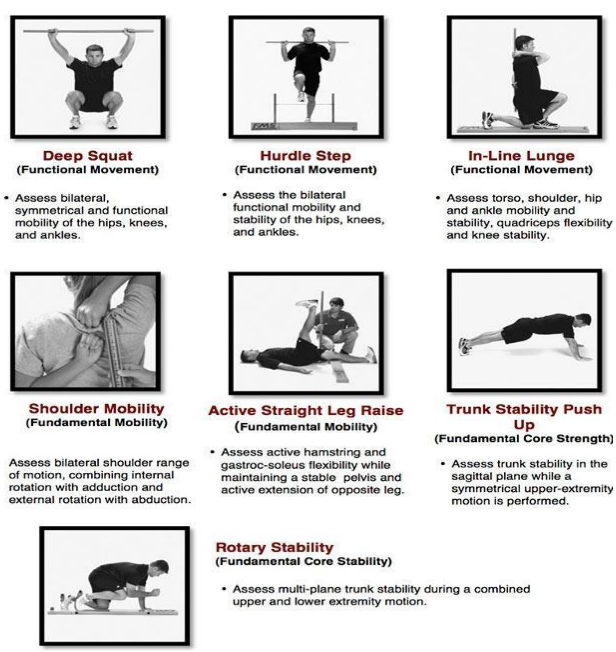


**Figure 1.** FMS Overview

## RESULTS

Characteristics: A total of 29 male firefighters completed the FMS test and the Occupational Performance Task. Their descriptive statistics are presented in Table 2 by the mean and standard deviation (SD). The age ranged from 23 to 50 years old, with an average age of 35.1 years (SD = 5.5 years). The average number of years in fire service was 11.11 (SD = 7.16); however, not all the firefighters disclosed their years of fire service, with 22 of the 29 having reported this information.

**Table 2**. Characteristics of study participants.

| Variable | *n* | Mean (SD) |
|---|---|---|
| Height | 29 | 181.57 (5.50) |
| Weight | 29 | 98.17 (18.50) |
| Age | 29 | 35.10 (8.77) |
| Body Mass Index | 29 | 29.82 (5.87) |
| Years of Fire Service | 22 | 11.11 (7.16) |

Occupational Task Performance: On average, firefighters completed this performance test in approximately 9 minutes.

Functional Movement Screen Composite Score: A multiple linear regression model was used to test the effect of age, BMI, max heart rate, and FMS total score on occupational total task time. The overall regression was statistically significant ($F(4,24) = 3.90$, $R^2adj = 0.29$, $p = 0.014$). Age had a statistically significant effect on occupational task time ($\beta = 7.44$, $p = 0.01$). BMI, max heart rate, and FMS total score did not have a statistically significant effect on occupational task time ($p$ = 0.13, 0.07, & 0.94, respectively). Regression coefficients and their standard errors are displayed in Table 3.

**Table 3**. Regression analysis FMS total score.

| Variable | *B* | 95% CI for *B* | β | t | P |
|---|---|---|---|---|---|
| Age | 7.44 | [2.44,12.44] | 0.56 | 3.07 | 0.01 |
| BMI | 6.22 | [-2.03,14.67] | 0.31 | 1.56 | 0.13 |
| Max Heart Rate | 3.6 | [-.32,7.52] | 0.35 | 1.9 | 0.07 |
| FMS Total Score | -0.57 | [-16.71,15.57] | -0.01 | -0.07 | 0.94 |

Note: *B* = unstandardized regression coefficient; CI = confidence interval; β = standardized regression coefficient; $R^2adj = 0.29$ ($N = 29$, $p = .014$)

Functional Movement Screen Asymmetries: A separate multiple linear regression was used to assess occupational total task time compared to age, BMI, and the presence of asymmetries. This multiple regression was different from the first regression by removing max heart rate and FMS total score and adding asymmetries to the independent variables. The overall regression was statistically significant ($F(3,25) = 3.61$, $R^2adj = 0.22$, $p = 0.027$). Age had a statistically significant effect on occupational total task time ($\beta = 5.8$, $p = 0.02$). BMI and asymmetries did not have a statistically significant effect ($p$ = 0.21 & 0.75, respectively). Regression coefficients and their standard errors can be found in Table 4.

**Table 4.** Regression analysis FMS asymmetries.

| Variable | *B* | 95% CI for *B* | β | t | *P* |
|---|---|---|---|---|---|
| Age | 5.8 | [1.05,10.57] | 0.44 | 2.51 | 0.02 |
| BMI | 4.5 | [-2.68,11.67] | 0.23 | 1.29 | 0.21 |
| Asymmetries | -13.85 | [-103.34,75.65] | -0.05 | -0.32 | 0.75 |

Note: *B* = unstandardized regression coefficient; CI = confidence interval; β = standardized regression coefficient; $R^2$adj = 0.22 ($N$ = 29, $p$ = 0.027)

Functional Movement Screen Elements: A point-biserial correlation was used to determine the correlation between all the FMS individual movements and occupational task time. There were twenty-one point-biserial correlations run, divided into seven tests, some of which were separated by left, right, and combined. For example, "Hurdle Step" is one element that was separated into Hurdle Step Left (L), Hurdle Step Right (R), and Hurdle Step Combined. Of the twenty-one correlations, four were found to be significant, with three of them being significant at the < 0.05 level and one at the 0.001 level. Inline Lunge L had a negative correlation with occupational task time and was statistically significant ($r_{pb}$ = -0.46, $p$ = 0.012); Inline Lunge R had a negative correlation of moderate strength ($r_{pb}$ = -0.583, $p$ = 0.001), Inline Lunge Combined had a negative correlation of moderate strength ($r_{pb}$ = -0.523, $p$ = 0.004), and Shoulder Mobility L had a negative correlation of moderate strength ($r_{pb}$ = -0.445, $p$ = 0.016). The remaining 17 correlations were not found to be statistically significant. Table 5 displays the correlations between the FMS individual elemental tests and occupational task time.

**Table 5.** Point-biserial correlation between FMS elements and occupational task time.

| FMS Tests | Pearson Correlation | Sig. (2-tailed) |
|---|---|---|
| Deep Squat | -0.019 | 0.923 |
| Hurdle Step L | -0.13 | 0.502 |
| Hurdle Step R | -0.141 | 0.467 |
| *Hurdle Step Combined* | -0.13 | 0.502 |
| Inline Lunge L | -0.46 | **0.012*** |
| Inline Lunge R | -0.583 | **0.001**** |
| *Inline Lunge Combined* | -0.523 | **0.004*** |
| Ankle Mobility L | -0.094 | 0.626 |
| Ankle Mobility R | -0.176 | 0.362 |
| *Ankle Mobility Combined* | -0.066 | 0.734 |
| Shoulder Mobility L | -0.445 | **0.016*** |
| Shoulder Mobility R | -0.113 | 0.561 |
| *Shoulder Mobility Combined* | -0.257 | 0.178 |
| Active Straight Leg Raise L | -0.213 | 0.268 |
| Active Straight Leg Raise R | -0.361 | 0.054 |
| *Active Straight Leg Raise Combined* | -0.283 | 0.138 |
| | -0.094 | 0.628 |

| | | |
|---|---|---|
| Trunk Stability Push-up | | |
| Rotary Stability L | -0.089 | 0.647 |
| Rotary Stability R | 0.069 | 0.721 |
| *Rotary Stability Combined* | -0.075 | 0.700 |

## DISCUSSION

This study explored the relationship between mobility and firefighters' occupational task time. Previous research established that firefighters often have limited mobility and may be subjected to an injury (7, 12), and the FMS test was designed to identify mobility hindrances that could predispose to injury (6, 12). The investigators hypothesized that there would be a significant effect of FMS score on the occupational task performance test, but it was found that FMS composite score was not significantly related to the completion of occupational task time ($p$ = 0.94). There was no difference between those with a high FMS score and a low FMS score when completing the task when using a cutpoint of 14. Potential reasons for not finding significance in the FMS scores and task time could be attributed to a lack of diversity in FMS scoring. The majority of the firefighters in this study were considered to have average mobility, scoring primarily as 2 across the FMS tasks. It is also possible that the firefighters were influenced by corrective exercises prescribed after their FMS assessment, which may have then affected their occupational task time since the FMS assessment was performed three months prior to the occupational task.

Although the overall FMS score was not related to task performance, some of the individual elements were found to be significant in relation to the occupational performance task time, including the Inline Lunge L, Inline Lunge Combined, Inline Lunge R, and Shoulder Mobility L. This means those that had a higher score on the Inline Lunge task were able to complete their occupational task faster than those with a lower score. Inline lunging movements occur when lowering our center of mass, often during deceleration, directional change, and dynamic squatting (11). During the occupational tasks, firefighters were required to perform inline lunge movements when picking up tools, transitioning from the ground to standing, pulling the fire hoses, or stopping after running to each station. If the firefighters were dysfunctional with inline lunge movements, they likely relied on compensatory movement patterns, which could explain slower times in the occupational performance task (6; 11). Prior research has also found Inline Lunge to be significant when comparing it to the Marine Corps Physical Fitness Test (PFT) (18). This study looked at individual components of the PFT and the FMS and found that the Inline Lunge was the only FMS component with a significant correlation, similar to our findings. This could be due to similar tactical populations and tasks required in these populations. Targeted exercises and training geared towards the Inline Lunge may potentially improve (decrease) overall occupational task time. These exercises should target static and dynamic motor control patterns such as half-kneeling step-up, toe-touch progression, split squat, leg lock bridge, or other similar movements (11). Further research is warranted on the effectiveness of targeted mobility exercises in improving occupational tasks.

Apart from the Inline Lunge, L shoulder mobility was also found to be correlated with occupational task time. Most of the firefighters in the department reported being right-hand dominant, which could be the reason for only having one shoulder being correlated. The FMS shoulder test assesses the shoulder in dynamic stability and balance, and the inability to correctly perform this test specifically has been shown to increase the risk of injury (26). This test also considers asymmetries and their effect on an increase in injury, suggesting an underlying impairment. Poor movement could result from the thoracic spine, scapula, or neck limitations as well as just the glenohumeral shoulder joint impairments. The FMS test does not include an isolated screening of the glenohumeral portion of the shoulder but rather an integrated look at reaching patterns (11). Therefore, the FMS should be completed fully, and one portion of the test cannot draw conclusions of lack of mobility, and asymmetries cannot be completely determined (11, 26). Firefighters do perform all fire suppression tasks in turnout gear which limits thoracic mobility, scapular, and neck movements (23). Therefore, the hindrance in mobility, specifically in one shoulder, could potentially be due to a dominant arm having an increased range of motion (ROM), carrying gear solely on that side, or wearing excess gear that further limits motion, and further research should be conducted to confirm. To improve ROM and mobility, firefighters should focus on corrective exercises geared towards both shoulders and not focus on one-sided movement patterns. These exercises can consist of breathing techniques, scapular and thoracic rotation, flexion, extension, and abdominal strengthening (11).

This study also investigated if asymmetries in the FMS lowered the occupational performance task time. We failed to reject this null hypothesis with a significance level of $p = 0.75$. Firefighters with asymmetries had similar times during the occupational performance task as those without asymmetries. Chapman also evaluated asymmetries; however, they studied athletes over a longitudinal period with corrective exercises prescribed in-between testing (4). They found those without asymmetries improved in their performance compared to those that had one or more asymmetries (4). Our study's analysis showed that this population had too much variability with a larger than expected confidence interval ranging from -103.34 to 75.65. This created difficulty in establishing conclusions and could explain why there was no significance in asymmetries and task time. To lower the variability and draw further conclusions, a larger population sample is needed to confirm this hypothesis.

Age was found to be significant in both multiple linear regression models. In relationship to the total score, it was found that older individuals had slower occupational task times by 0.56 seconds. We expected this correlation noting the dissipation firefighting puts on an individual's body. Research has also found this to be significant in terms of body fat percentage. Saupe found as early as 1991 that the older the firefighter was, the more their mobility decreased and their body fat increased (24). Another study found that age and BMI affected performance in certain firefighting tasks, similar to what our study investigated (16).

This study is unique as it is the first to explore the relationship between firefighters' mobility in relation to their occupational task performance, whereas the majority of studies thus far have focused on FMS and its relationship to injury risk (1, 5, 7, 12, 15, 16, 26). Chobra (2010) found that compensatory movements could increase the risk of injury in female athletes, specifically in soccer, volleyball, and basketball at the Division II level (5). This was identified using the FMS two weeks prior to the athletes starting their seasons. FMS scored ≤ 14 points were considered dysfunctional. Our study was designed to be exploratory in nature and utilized individual scores per FMS guidelines, whereas other studies have utilized the alternative method interested in injury prevalence (15, 22).

Our study is similar to that of Bock (2016), evaluating police recruits who completed different tasks such as marksmanship, defensive tactics, baton strikes, tactical options, as well as the FMS. The major differences were that we measured our occupational task in time, whereas they did individual tasks measured by a score (1). They also conducted their FMS scores as pass/fail, whereas we measured by collecting individual scores per FMS guidelines. This study had no significant findings that were congruent to previous research that suggests poor movement patterns predict poor occupational performance tasks.

There are multiple limitations that must be considered in the current study. The first is that this study was conducted using retrospective data from a convenience sample of rural firefighters. This study also had a small sample size which means that this study may not have been adequately powered to be able to draw conclusions or generalize on the current firefighting population. A post hoc power analysis using the first regression revealed an achieved power of 0.54 ($\alpha = 0.05$). If a larger sample size had been utilized, this study may have been able to draw further conclusions. Another limiting factor was that the FMS was designed to best assess those with poor movement patterns and was utilized to assess healthy and active firefighters with average movement patterns. This study also assumes that the participants put forth full effort in the FMS and during the occupational task. Future research should sample larger cohorts to strengthen their data and potentially be able to draw better conclusions.

Firefighting is a dangerous profession, and there is a need to mitigate potential injuries. Research has shown the FMS can easily be utilized for injury prevention and performance predictability by identifying pain and poor movement patterns, and previous FMS research has suggested lack of mobility can lead to the potential for injury and poor performance in athletic populations. It is evident that Inline Lunge may be a key element in the occupational performance task for firefighters. Corrective exercises focusing on deceleration and dynamic squatting may improve the occupational task. Future research should strive to increase the sample size to draw further supported conclusions.

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