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Original Research

Age and Postural Stability in Firefighters: An Analysis of Anterior Reach Asymmetry and the Two-Foot Length Criterion

Madeleine Fulk*[1], Roger O. Kollock‡[1], Maddie Seidner*[1], Rachel Ward*[1], Zora Szabo*[1], Muhammad O. Malik†[1], and Gabriel J. Sanders‡[2]

[1]Department of Kinesiology and Rehabilitative Sciences, The University of Tulsa, Tulsa, OK, USA; [2]University of Cincinnati, Cincinnati, OH, USA

*Denotes student investigator, †Early-Career Investigator, ‡Denotes established investigator

Abstract

International Journal of Exercise Science 18(8): 1175-1185, 2025. https://doi.org/10.70252/HSMV3009 This study explored how age affects postural stability (PS) in firefighters by focusing on two key objectives: 1) determining if age affects right-to-left anterior (ANT) reach distance asymmetry (ASYM) during the Motor Control Screen (MCS) test and 2) assessing whether the proportion of firefighters not meeting the greater than two-foot length (2FL) criterion for ANT reach differs across age groups. Data from 95 male firefighters were analyzed using the MCS ANT reach test, part of the Y-Balance Test (YBT). The key outcomes were the difference in ANT reach distances between legs (ASYM) and the proportion reaching less than or equal to 2FL. Statistical analyses used Mann-Whitney U tests for ASYM and chi-square tests for proportions. No statistical difference in ASYM was found between younger and middle-aged firefighters ($U=1025$, $p=0.501$, $r=-.069$). Similarly, the proportion of firefighters not meeting the greater than 2FL criterion did not significantly differ across age groups for both right and left ANT reaches ($p= 0.997$, $\varphi=.000$ for right and $p= 0.547$, $\varphi=-.062$ for left). These findings indicate that age does not significantly influence right-to-left ANT reach ASYM or the likelihood of failing to meet the greater than 2FL criterion in this firefighter population. The results suggest that PS, as measured by ANT reach ASYM and the greater than 2FL criterion, does not significantly decline with age among firefighters. This may be due to the physical demands of firefighting. Future research should explore how ANT reach measures relate to injury risk and evaluate age-specific balance training interventions.

Keywords: Balance assessment, Motor Control Screen, Y-Balance Test, injury risk

Introduction

In recent years, the combined injuries resulting from slips, trips, and falls (STFs) accounted for 22% of all injuries sustained by firefighters at the fire scene, behind only overexertion/strains (31%).[1] There is evidence to suggest that the high number of injuries resulting from STFs may be related to a firefighter's ability to maintain stability on slippery[2] or unstable surfaces[3] while donning fire-specific equipment and gear. This ability to maintain stability by controlling one's body positioning in space during a given activity, termed postural stability (PS), is important in the maintenance of equilibrium in both static and dynamic tasks.[4] PS relies on a continuous feedback system of processing visual, vestibular, and somatosensory inputs and executing neuromuscular action.[5] The influence of age may also play a role in a firefighter's susceptibility to STFs. Age-related changes in PS in healthy adults are well documented.[6-9] Balance ability is not stable across a person's life span, but peaks in young adulthood and gradually declines as a person ages.[7,10] As a person ages, their ability to make postural adjustments may be compromised due to a variety of factors, such as deterioration of lean body mass[11,12] or degradation of the sensory systems.[13] To date, there is limited research exploring the effect age may have on PS in fire and rescue personnel. Gaining a deeper understanding of how age affects PS may provide fire departments with valuable insights for designing strength and conditioning programs aimed at reducing the risk of STFs.

PS can be assessed statically or dynamically through four subdivisions of tests: static steady-state balance, dynamic steady-state balance, proactive balance, and reactive balance.[14] In athletic populations, the use of proactive balance tests, such as those that require the participants to balance on one leg while reaching with the contralateral leg in the anterior (ANT), posterolateral, and posteromedial directions along a measured distance (e.g., Star Excursion Balance Test [SEBT] and Y-Balance Test [YBT]), have received considerable attention as a means of identifying athletes at risk for lower extremity injuries.[15] Based on the SEBT, the YBT is a simple clinical tool that is a reliable and valid means of evaluating dynamic balance.[16-18] In the ANT reach direction, reports indicated minimal differences between the YBT and SEBT, suggesting that both tests can provide comparable measures of balance in this reach direction.[19] The test can be shortened to include only the ANT reach distance as the ANT reach distance is strongly correlated to the posteromedial (r=.78) and posterolateral (r=.66) reach directions.[20] ANT reach distance is often reported normalized to lower limb length, as calculated by the ANT reach distance divided by lower limb length (anterior superior iliac spine to medial malleolus), multiplied by 100.[21] Furthermore, ANT reach asymmetry (ASYM) is defined as the absolute difference between the right and left ANT reach distances.[21-24]

ANT reach distance is an injury risk factor in professional soccer,[25] division I collegiate,[22,23] and high school athletes[21] with estimated normalized ANT reach cut-off values ranging from 54.5% to 67% depending on the type of injury and level of athletes.[15,25,26] It has also been observed that firefighters and traditional athletes with an ANT reach ASYM greater than 3 and 4 centimeters, respectively, have a significantly greater chance of injury.[21-24] In a sample of French firefighters, investigators reported observing that the ANT reach distance in firefighters suffering ankle sprains significantly differed from those that did not suffer an ankle sprain.[24] The researchers also observed that a right-to-left ASYM difference cut-off score of greater than 3 centimeters could be used to classify lateral ankle sprain injury risk (77.8% sensitivity; 80.0% specificity).[24]

The makers of the Functional Movement Screen (FMS) have developed the Motor Control Screen (MCS). The MCS incorporates the ANT reach aspect of the YBT and allows for the evaluation of right-to-left ASYM. To perform the MCS, practitioners use the FMS test kit (61" x 7" x 2" plank) and slide box (Functional Movement Systems, Inc., Chatham, VA, USA) to perform an ANT reach for distance (Figure 1). However, there are notable test differences between the YBT and MCS. The MCS is performed with shoes, the performer does not maintain their hands on their hips, and the test includes an additional scoring criterion of reaching greater than two times the foot length (2FL).

Although ANT reach distance and right-to-left ASYM have been explored as injury risk factors, to the authors' knowledge there is no research exploring the influence age may have on ANT reach distance and level of ASYM in persons employed in tactical occupations such as fire, law enforcement, and military. There are, however, limited studies investigating the relationship between age and YBT composite scores (average of the three reach distances normalized by lower limb length) as an indicator of balance ability in tactical athletes.[27,28] It has been observed that active-duty military personnel ≥30 years of age demonstrate poorer balance with significantly lower YBT composite scores ($p=.003$),[27] but a study of police officers found that age was not significantly correlated to YBT composite scores ($r=-.197$).[28] This difference in findings necessitates further investigation in this area. Most of the available literature investigating the relationship between age and ANT reach metrics has been conducted in healthy non-tactical populations.[6-8] In addition, previous research has not explored the effects of age on ANT reach ASYM. The available literature has focused on the effect normal aging has on ANT reach distance in healthy adults.[6-8,13,29,30] This has been done by comparing children and adolescents to younger adults or by comparing younger adults or middle-aged adults to older adults.[6,8] Normal age classifications are defined as follows: infancy (birth to 2 years), childhood (2 to 12 years), adolescence (12 to 18 years), and adulthood (18 years and older).[31]Adulthood is further divided into young adulthood (18-40 years), middle age (40-60 years), and older adulthood (60 years and older).[31] Findings appear to suggest that age does play a role in a healthy person's balance ability with younger and middle-aged adults presenting better balance ability as compared to older adults.[6,8,14] The literature also suggests that there is no significant difference in ANT reach distance between children, adolescents, and young adults.[30] These same findings may not be directly applicable to those working in tactical occupations such as firefighting because there are no direct comparisons between younger adults and middle-aged adults. This could be problematic as, according to the National Fire Protection Agency, the combined population of these two demographics represents 87% of firefighters, with 47% of the firefighter population comprised of younger adults ages 20-39 and 40% middle-aged adults ages 40-59.[32] Those 60+ years of age only represent about 10% of firefighters.[32] Therefore, it is difficult to justify generalizing the findings of previous studies to firefighters. A direct comparison of younger and middle-aged adult firefighters could help address this gap in the literature. The heightened risks for injuries due to STFs in the firefighter population necessitate we explore if firefighters experience similar age-related declines in PS. An observation of age-related decline in ANT reach distance may suggest the need for targeted balance interventions for middle-aged firefighters to minimize the risk of STFs.

Thus, the primary purpose of this study was two-fold: 1) determine if ANT reach ASYM differs across age groups and 2) determine whether the proportion of those not meeting the greater than 2FL criterion differs across age groups. We hypothesized that there would be a significant difference in ANT reach ASYM between age groups. Moreover, we hypothesized that the proportion of those not meeting the greater than 2FL criterion would significantly differ between age groups.

Methods

The study was a retrospective analysis of archived data from a medium-sized metropolitan fire department in the southwest United States that operates 30 fire stations and responds to approximately 401,190 permanent residents. The data was collected as part of the fire department's annual fitness assessments for their incumbent firefighters.

Participants

Archived data from 96 male firefighters were analyzed for this retrospective study. One participant was excluded from the sample due to missing data. Therefore, statistical analyses were run with the remaining sample of 95 male firefighters. Firefighters were allocated to one of two groups based on their age: younger adults (20-39 years) and middle-aged (40-60 years). The age classifications were adopted to allow for comparison with previously reported literature.[31] All firefighters included in the dataset were career firefighters and 18 years of age or older. Firefighters restricted from duty were not eligible to participate. The use of the data was approved by a university review board (Protocol 24-64) and a collaborating fire department. Upon arrival to the site of the fitness assessments, firefighters were informed about the aims of the potential utilization of their data for research purposes and signed the associated informed consent document. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.[33]

Protocol

All participants reported to the fitness testing session wearing shorts and t-shirt provided by the fire department and personally selected sneakers. As part of the annual fitness assessment, each firefighter's blood pressure, pulse, body weight, body fat percentage, and height were assessed prior to the start of any physical activities. The annual fitness assessment included the following assessments of muscular strength and power: grip strength (right and left), isometric mid-thigh pull, and vertical jump. For muscular endurance, the firefighter could perform 1-minute of push-ups or 1-minute of sit-ups. After all muscular strength and endurance assessments and before the FMS shoulder mobility test, FMS active straight leg raise test, and a multi-stage aerobic step test to 85% of their maximum heart rate, the firefighters performed the MCS ANT reach test as their measure of PS. The MCS ANT reach test is based on the YBT. The MCS only includes the ANT reach aspect of the YBT (Figure 1). The ANT reach distance was measured in inches (in) and converted to centimeters (cm). Before the start of the assessment, foot length with sneakers on was determined using the 61" x 7" x 2" FMS test kit plank (Functional Movement Systems, Inc., Chatham, VA, USA), which has a measurement ruler inscribed on its surface. Foot length was used to determine if the participants were able to reach a distance in the ANT direction greater than 2FL, which is a scoring criterion of the test.[34,35] Participants were given three trials on both the right and left legs. To perform the ANT reach test, the participant stood with one foot on the FMS test kit plank, with the most distal aspect of the shoe just behind the red starting line. The participant was instructed to maintain a single-leg stance while performing a reach in the ANT direction by pushing a slide box with the toes of the free limb. After pushing the slide box as far forward as possible the participant then returned to the starting stance. The participant had to perform the reach without touching the free limb to the floor. If the free limb touched the floor, the trial was invalid. The test was performed with shoes.[34,35] The furthest reach was recorded for the right and left sides. Participants were encouraged to perform the test with maximum effort and were made aware of their score for each trial via both their own visual inspection of the test kit plank and verbal reporting.

Figure 1. Firefighter reaches for distance during the MCS ANT reach test

Statistical Analysis

The absolute difference between the right and left reach distance (cm) [|right reach (cm) – left reach (cm)|] was used as the measure of ASYM. All data were checked for normality using a Shapiro-Wilk Test. A significant departure from normality was indicated by a significant Shapiro-Wilk test ($p \leq .05$). The Mann-Whitney U Test was used to explore between-group differences in right-to-left ANT reach ASYM because the data failed the assumption of normality (Shapiro-Wilk Test, $p < .05$). The effect size, r, was calculated by dividing the Z value by the square root of the number of participants.[36] This value ranges from -1 to 1 and was interpreted using the following scale: $|r| < 0.3$ is considered a small effect, $0.3 \leq |r| \leq 0.5$ is considered a medium effect, and $|r| > 0.5$ is considered a large effect.[37] Three paired-samples t-tests were used to investigate within-group differences between right and left ANT reach distances in the younger adults group, middle-aged group, and the complete sample as a secondary analysis of right-to-left ANT reach ASYM. Two separate tests of two proportions using the chi-square test of homogeneity were conducted to determine if the proportion of individuals not meeting the greater than 2FL criterion differed between age groups for both the right and left ANT reach. Phi (φ) coefficients were calculated to determine effect sizes for each test. These effect sizes range from -1 to 1 and were interpreted using the following scale: $|\varphi| < 0.3$ is considered a small effect, $0.3 \leq |\varphi| \leq 0.5$ is considered a medium effect, and $|\varphi| > 0.5$ is considered a large effect.[37] The alpha level (p-value) was set at .05 for all comparisons. All data was analyzed using SPSS Statistics 28.0.1.1 (IBM Corp., Somers, NY).

Results

95 firefighters were retrospectively assigned by age to either the younger adult (n=53) or middle-aged (n=42) firefighter group. Demographics, anthropometrics, and body composition measurements of the firefighters are found in Table 1. No significant difference was found in right-to-left ANT reach ASYM between age groups as indicated by the Mann-Whitney U test (U= 1025, p=0.501, Z=-.673) with a small effect (r=-.069). Paired-samples t-tests found no statistically significant differences between right and left ANT reach distance for the younger adults group (p=.356), middle-aged group (p=.957), or the complete sample (p=.444). Table 2 summarizes the means and standard deviations of right ANT reach, left ANT reach, and right-to-left ASYM for each group. Two separate tests of two proportions ran using the chi-square test of homogeneity found that 54.7% (n=29) of firefighters in the younger adult group had a right ANT reach less than or equal to 2FL as compared to 53.5% (n=23) in the middle-aged group (Table 3). There was a non-statistical difference in proportions of .000, p =. 997 with no effect (φ=.000). For the left ANT reach, 50.9% (n=27) of firefighters in the younger adult group had a left ANT reach less than or equal to 2FL as compared to 57.1% (n=24) in the middle-aged group (Table 4). There was a non-statistical difference in proportions of -0.043, p =.547 with a small effect (φ=-.062). No adverse events occurred during fitness assessment sessions.

Table 1. Demographics, Anthropometrics, and Body Composition of Career Firefighters

	Younger Adults (n = 53)	Middle-aged (n = 42)
Age (yrs.)	31.64 ± 5.33	45.88 ± 3.97
Height (cm)	178.27 ± 6.84	178.18 ± 6.62
BW (kg)	89.21 ± 15.76	97.10 ± 22.90
FL (cm)	31.03 ± 1.98	31.08 ± 1.80
BMI	27.97 ± 4.41	30.36 ± 6.05
BF %	19.76 ± 5.99	24.28 ± 7.21

yrs. = years, cm = centimeters, BW = body weight, kg = kilograms, FL = foot length, BMI = body mass index, BF% = body fat percentage.

Table 2. Right and Left ANT Reach Distances with ASYM

	Younger Adults (n = 53)	Middle-aged (n = 42)	Total (n = 95)
Right ANT Reach (cm)	63.12 ± 7.34	62.29 ± 6.74	62.75 ± 7.06
Left ANT Reach (cm)	62.59 ± 7.53	62.26 ± 6.68	62.44 ± 7.13
ASYM (cm)	2.92 ± 2.92	2.87 ± 2.19	2.90 ± 2.61

ANT = anterior, ASYM = asymmetry, cm = centimeters

Table 3. Participant Achievement of Greater than 2FL Criterion for Right ANT Reach

	Younger Adults (n = 53)	Middle-aged (n = 42)	Total (n = 95)
>2X FL	24 (45.3%)	19 (46.5%)	43 (45.8%)
≤2X FL	29 (54.7%)	23 (53.5%)	52 (54.2%)

FL = foot length, ANT = anterior, >2X = greater than two times, ≤2X less than or equal to two times

Table 4. Participant Achievement of Greater than 2FL Criterion for Left ANT Reach

	Younger Adults (n = 53)	Middle-aged (n = 42)	Total (n = 95)
>2X FL	26 (49.1%)	18 (42.9%)	44 (46.3%)
≤2X FL	27 (50.9%)	24 (57.1%)	51 (53.7%)

FL = foot length, ANT = anterior, >2X = greater than two times, ≤2X less than or equal to two times

Discussion

This is the first study to evaluate the effect age has on firefighter balance ability. The main findings of the study were that 1) ANT reach ASYM measured using the MCS did not significantly change with increased age and 2) nor did the proportion of firefighters having an ANT reach less than or equal to 2FL significantly differ between those in younger adulthood as compared to those who were middle-aged. This was an interesting finding considering several studies have demonstrated age-related changes in balance.[6,30,38]

We hypothesized that there would be significant differences in ANT reach ASYM between age groups. Our findings did not support this hypothesis. The degree of ANT reach ASYM in centimeters does not appear to significantly change with age. The researchers could only identify one published study that has explored the effects of age on ANT reach distance ASYM.[30] However, the study used a sample ranging from 10-18 years of age.[30] The group observed that there was not a significant difference in ASYM in the ANT direction across the following age groups: 10-12 years (3.37±.47), 13-15 years (3.24±.30), and 16-18 years (3.01±.42).[30] In this previous study, the level of ANT reach ASYM appeared to decrease with age, although not significantly. This was a trend observed in the findings of the present study, although this is a difficult comparison as the cited study demonstrates the effects of maturation rather than adult aging. The younger groups had the highest mean absolute right-to-left differences (Table 2). The mean values between groups did not statistically significantly differ, with the younger group having a mean of 2.92 centimeters and the middle-aged group having a mean of 2.87 centimeters, coming to a non-statistical difference of 0.05 (Table 2). This places the firefighters within the present study under the 3-centimeter cut-off score reported in the previously referenced study of French firefighters.[24] The level of ANT reach ASYM observed in the present study is not surprising. A secondary analysis indicated there were no statistically significant within-participants differences between right and left ANT reach distances within the younger adults group, and middle-aged group, or the complete sample (p's>.05). Thus, our findings are in line with previous research, including one systematic review indicating there are no significant differences between dominant and nondominant ANT reach distance.[39] However, it is possible that the physically demanding nature of firefighting, including regular training and physical activity, may mitigate the typical age-related declines in balance seen in other populations. Firefighters, through their occupation, may maintain higher levels of PS and balance, which could explain the lack of significant changes in ANT reach ASYM across age groups. Additionally, our findings suggest that middle-aged firefighters may not experience significant age-related declines in PS, implying that balance-focused interventions may not need to be adjusted for this population. However, given that slips, trips, and falls (STFs) remain a significant risk for firefighters,[1] balance training should not be entirely disregarded. These results can inform future fitness assessments and training protocols tailored to occupational needs ensuring that any potential balance deficits are addressed in a timely manner.

We also hypothesized that the proportion of firefighters below the greater than 2FL criterion would significantly differ across age groups. The findings of the present study did not support this hypothesis. This was observed for both the right and left ANT reach. Unfortunately, there is no research supporting the use of the greater than 2FL criterion. Future studies should investigate the relationship between the 2FL criterion and injury risk in firefighters as well as the validity of normalizing ANT reach distance to foot length instead of lower limb length. If valid and significantly related to ANT reach distance normalized to lower limb length, normalizing ANT reach distance to foot length would allow for a simple, more time effective method of normalization as foot length is recorded as part of the MCS protocol in order to determine the 2FL criterion.

Our results also differ from previous observations in females. Lee et al (2015) found a significant difference between age groups ($p<0.007$) for both right and left YBT ANT reach for middle-aged (45-60 years) women (R: 0.782±0.046; L: 0.77±0.049) and older (70-80 years) women (R: 0.624±0.058; L: 0.631±0.058).[6] The difference observed in the present study may be a result of the age groups explored. It is possible the degenerative changes related to age are more pronounced between younger and older adults as well as between middle-aged and older adults. It is also possible that age-related changes in balance ability may impact males differently as compared to females. All the previous studies included females in their analyses, while the present study consisted of only males. In addition, because firefighters must don heavy loads (bunker gear and self-contained breathing apparatus) on slippery or unstable surfaces as a part of their occupation, it's possible vocation may act as a mitigating factor across age groups in firefighters. Balance is not the only motor ability found to decline with aging. Muscle strength also declines with normal healthy aging; however, engaging in frequent physical activity would help to slow age-related degeneration of muscle tissue.[40,41] Maintaining strength and power into middle age arguably shows some level of engagement in physical activity, which may help in the persistence of a firefighter's balance ability. Studies have reported the benefits of physical activity for improving strength and balance.[40,41]

The authors of the present study acknowledge the following limitations. First, this is a retrospective analysis. Thus, there could be a potential for incomplete documentation. Second, females were also not represented in this sample, so findings cannot be generalized to female career firefighters. The National Fire Protection Agency estimates that 1,260 female firefighters are injured on the fireground each year.[42] Data also suggests that 16% of female firefighter injuries on the fireground result from a slip or trip.[42] Third, the MCS requires the test be performed shod. This may have resulted in inflated ANT reach distances or introduced differences based on the sneaker worn. Future studies should be conducted to explore the comparability between shod and barefoot measures. Moreover, firefighters wear departmentissued boots while on the fireground, where injuries are most frequently sustained,[1] but wore athletic sneakers when reporting to the fitness assessment sessions. Due to the retrospective nature of this study, this standard workout dress per the fire department was worn. This provides an interesting future direction of comparing firefighter ANT reach distance and ASYM while wearing boots versus sneakers.

The level of ANT reach ASYM does not appear to significantly change between the ages of 20 and 59 in career firefighters. The proportion of firefighters having an ANT reach less than or equal to 2FL did not significantly differ between those in younger adulthood as compared to those who were middle-aged. Future studies should explore if there is a relationship between ANT reach ASYM or having an ANT reach less than or equal to 2FL and injury susceptibility in fire and rescue populations.

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Corresponding author: Roger O. Kollock; roger-kollock@utulsa.edu