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Movement quality and links to measures of fitness in firefighters

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Abstract.
BACKGROUND/OBJECTIVE: Given the possible links between movement, fitness and injury, the goal of this study was to evaluate strength, endurance, and hip range of motion (ROM) (i.e. fitness); movement quality; and age in a population of firefighters.
PARTICIPANTS: Male firefighters ($n = 282$), all members of a major Canadian city fire department, volunteered to participate in this cross-sectional study.
METHODS: Torso endurance, grip strength, pull-ups, hip ROM, movement quality (sum of 7 movement tasks graded on a 0–3 scale), age, body mass, height, body mass index, and hip and waist circumference were assessed in 282 Firefighters. Relationships between variables were evaluated and compared to relevant populations (i.e. police officers, other firefighters, athletes, students and healthy males).
RESULTS: There was no relationship between age and fitness or movement quality. Compared to other populations, our firefighter population had poorer torso endurance but similar grip strength. Larger body mass, waist circumference and hip width were correlated ($p < 0.01$) with poorer Total Movement Score. Back extensor endurance (Biering-Sorensen test) was found to have the strongest relationship with Total Movement Score in comparison to all other tests. Notably, the extensor endurance and pull-ups were related to five of nine tasks each. The magnitude of hip ROM asymmetry related only to the stand-sit-stand movement test. In general, correlations between variables were relatively low, suggesting that most of these variables are independent and/or unrelated to one another.
CONCLUSIONS: Movement quality is not strongly correlated with traditionally utilized markers of fitness, nor is movement linked to age. This would imply that training should include movement competency components together with traditional fitness objectives.

Keywords: Hip range of motion, strength, movement quality, torso endurance, database

1. Introduction

Firefighting is a physically demanding occupation that often requires incumbents to be prepared for the unexpected. Several scientific investigations have sought to understand the physical demands of the job so that training programs can be developed to enhance a firefighter's performance while also reducing their risk of injury. Unfortunately, injuries shorten the careers of many well trained firefighters [1,2]. Attempts to understand these occupational injuries frequently consider the relationship with worker fitness. Fitness testing in the fire service has traditionally included assessments of strength [3]; flexibility and joint range of motion [4]; torso endurance [5]; and physiological variables, such as heart rate and/or blood pressure [6]. However, evidence exists to suggest that efforts to improve fitness alone may not ensure peak performance or injury resilience [7,8]. Previous injury is a primary risk factor for future injury, in part because injuries change the way a person moves as an accommodation to pain

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(consider limping from foot pain which changes the mechanics throughout the anatomical linkage). Having a history of injury, in particular back injury, appears to change movement patterns [9–11]. An individual's movement patterns influence their risk of injury by modulating joint and tissue loads and the length of time or repetitions that can be performed safely and effectively. Adopting compensatory strategies can expose the passive tissues to inordinate load, thereby elevating the individual's risk of injury. For example, failing to maintain a neutral curve in the lumbar spine while bending and lifting decreases the tolerable load [12]; having restricted hip motion causes more spine motion when bending [9]; hip asymmetry is linked to subsequent back injury [13]; and having larger knee abduction moments and angles when landing from a jump has been associated with a higher risk of ACL injury [14]. These variables are not job specific but generic to any physically demanding occupation.

Given the variety of considerations for interpreting the links between movement, fitness and potential injury, the goal of this study was to evaluate select markers of muscular strength, endurance, hip joint range of motion and movement competency in a group of professional firefighters that perform physically demanding tasks (requiring movement and fitness) every single day. It was hoped that investigating the links between specific tests of fitness and movement quality would reveal relationships to identify the most influential variables to be included in future studies.

Aging of the workforce is another relevant concern motivated by population demographics. Little is known about the changes that occur in a firefighter's physical abilities over the duration of their career; therefore, it is possible that their "fitness profile" could be age dependent. Study of fitness in occupational groups has suggested that being fit, at least using a physiological definition based on energy system markers, is generally associated with fewer numbers of injury (in a large cohort of firefighters) [6]. However, what is not known is the influence of movement quality on traditional markers of fitness and performance.

This notion motivated the attempt in this paper to quantify movement in a systematic way. This is difficult, however, because the criterion of "good movement" depends on the context. For example, the movement objective to walk across a roof during a rescue would be very different than the movement required to carry the rescued victim down a ladder. Nonetheless, because compensatory motion has been linked to injury [14], many scientists and practitioners now include movement screens to evaluate risk of injury [15–19]. In addition, other attributes of fitness, such as hip range of motion, have been suggested to be related to injury (e.g., while tighter hips were not strongly related to developing back pain, asymmetry in hip motion was [13]). Knowing the links between hip asymmetry, movement quality and other markers of fitness may be helpful. For all of these reasons, a battery of movement tasks, and tests of torso endurance, muscular strength and hip joint range of motion were incorporated into this study.

It was hypothesized that movement and fitness scores would be influenced by age in this group of firefighters, further that traditional measures of fitness (i.e. torso endurance, strength and hip joint asymmetry) would not predict the quality of an individual's movement, regardless of age. It was also hypothesized that variables of fitness would not predict the quality of movement demonstrated while performing of an unconstrained loaded task, and that there would be specific tests that could better predict the overall quality of movement.

2. Methods

2.1. Participants

Male firefighters ($n = 282$), all members of a major Canadian city fire department, volunteered to participate in this cross-sectional study. Their mean (SD) age, height and body mass were 36.5 (± 9.4) years, 1.79 (± 8.4) m, and 88.7 (± 10.7) kg, respectively. Because their job requires physically demanding exertions, the fire department also supports and encourages participation in a regular fitness program. Each participant read and signed an informed consent approved by the University Office for Research Ethics.

2.2. Procedures

Collection took place in sessions lasting approximately 2.5 hours prior to any type of work-related physical training. Personal information was recorded, including age, height, body mass, from which Body Mass Index (BMI) was calculated, and waist and hip circumference. Subjects were asked to perform 9 movement tasks, and measures of torso endurance, strength and hip range of motion (ROM) (for a measurement of asymmetry) were collected. The order of testing was randomized.

2.2.1. Movement tasks

Movement quality was assessed with 7 tasks, each of which was graded on a 0–3 scale, using criteria

Table 1
List of movement tasks. These tasks included some from the "Functional Movement Screen" (tasks 3,4,5,8,9) together with others that incorporated more load and range of motion (tasks 1,2,6,7). They were performed with no specific movement-related instructions

Task	Description
1) Coin lift:	The participant lifted a coin from the floor. The focus was on spine sparing movement through the strategy the participant chose to use.
2) Box lift:	A 40 cm square box, weighted with 18 kg, was lifted from handles 20 cm from the floor. The focus was on the "hip hinge" rather than spine motion.
3) Torsion control:	Taking a pushup posture, the participant placed one hand to the opposite elbow. The focus was on the ability to constrain twisting movement.
4, 5) Single leg squat (right and left sides):	A one legged squat was performed on both the right and left side. The focus was to balance, while displaying hip mobility and competency to return to upright.
6) Stand-sit-stand:	From a standing position, the participant was asked to sit on a stool and return to standing. Focus was put on hip dominance in the movement and balance control.
7) Stand, drop, stand:	From a standing position, the participant dropped face down on the floor and returned to standing. Focus was on the strategy chosen to rise from the floor, be it a squat or lunge strategy, and general movement competency.
8, 9) In-line lunge (right and left sides):	With both feet aligned and a dowel held in contact with the head, upper back and sacrum, a split squat was performed. Focus was on the strategy chosen to squat down and up. This task, unlike the others, was defined as constrained given that the participants were required to begin in a specific position (i.e. feet aligned, dowel behind their back).

that have been hypothesized to be predictive of musculoskeletal pain or injury (e.g. spine flexion with hip flexion, a medial collapse of the knee) [11,14,20,21]. These tasks included some from the "Functional Movement Screen" (tasks 3,4,5,8,9) together with others that incorporated more load and range of motion (tasks 1,2,6,7) (see Table 1). The movement scores for all seven tests (9 total because two required left and right side performance) were summed to produce a "Total Movement Score". A higher score signified better movement competency.

2.2.2. Measures of torso endurance

2.2.2.1. Biering-Sorensen extension

The upper-body was cantilevered over the end of a bench with the pelvis (anterior superior iliac spine) in line with the edge of the bench. The knees and hips were secured. The test began with the participant supporting his own upper body mass and the arms positioned across the chest, while a straight-body position was held, and ended when the horizontal position could no longer be maintained. This test was first used as a test of back muscle endurance by Biering-Sorensen [22] and has been tested for reliability (reliability coefficient of 0.98 over 5 days of repeated tests, and 0.99 after 8 weeks [23]).

2.2.2.2. Side plank

Participants were placed in a side lying position and asked to raise themselves off the floor with their elbow and feet (the top foot was placed in front of the bottom foot). The test began once a straight-body position was attained with a neutral spine (spine curvature similar to that when standing) and ended when the position could no longer be held. This test was performed on both the right and left sides. Reliability coefficients for this test were observed in a previous study of 0.99 over 5 subsequent days, and 0.96 after 8 weeks [23].

2.2.2.3. Front plank

Beginning in a prone position, participants lifted themselves off the ground with their elbows and toes. The test began with a neutral spine position (again, a similar spine curvature to a standing position) and ended when the position could no longer be held. Reliability coefficients for this test were observed in a previous study of 0.97 over 5 subsequent days, and 0.93 after 8 weeks [23].

2.2.3. Measures of strength

2.2.3.1. Grip strength

Sitting in a chair with no arm rests, the participant's shoulder was adducted at zero degrees of flexion, the elbow flexed to 90° and the wrist placed in a neutral position [24]. A hand dynamometer (Takei Kiki Kogyo, Nigata, Japan) was used to record a maximal effort with each hand. This served as an absolute measure of strength, recorded in kilograms.

2.2.3.2. Pull-up repetitions

Participants used an overhand grip to perform pull-ups until failure with their hands positioned at shoulder width (to normalize grip distance). The chin was required to reach the height of the hands for each repetition to be recorded, but cadence was not controlled. This test was used to provide a measure of relative strength, or the ability to handle one's body mass.

2.2.4. Measures of hip ROM

2.2.4.1. Hip extension (knee flexed)

Lying supine with the non-test leg's hip and knee flexed (i.e. Thomas test position), the research assistant ensured that the spine was in a neutral position. The test leg's knee was flexed to 90° and lowered passively. Hip extension was recorded as the angle between the horizontal and a line between the greater trochanter and the lateral epicondyle of the femur (positive was greater ROM), measured with an orthopaedic goniometer. This test was performed for both the right and left legs.

2.2.4.2. Hip extension (knee extended)

The test leg was extended (0° knee flexion) and a second hip extension measurement was taken. This test was performed for both the right and left legs.

2.2.4.3. Hip flexion (knee flexed)

Lying supine on a bench with a neutral spine and the non-test leg fully extended, the test leg was placed in 90° knee flexion and raised by the research assistant until spine motion was noted. Hip flexion was recorded as the angle between the horizontal and a line between the greater trochanter and the lateral epicondyle of the femur. This test was performed for both the right and left legs.

2.2.4.4. Hip flexion (knee extended)

The test leg was extended (0° knee flexion) and a second hip extension measurement was taken. This test was performed for both the right and left legs.

2.3. Statistical analysis

Scores were tabulated and evaluated for relationships to one another. Those scores with a ratio scale (e.g. strength in kilograms or torso endurance in seconds) were assessed with a Pearson moment correlation, while scores with an ordinal scale (e.g. movement competency scored with the 0–3 scale) were assessed with a Spearman rank order correlation. Normality was confirmed for all variables with Q-Q plots. There was one outlier in each of the waist and hip circumference measures and two outliers in the left grip strength measure. Outliers were included in the analyses. This approach facilitated later comparisons with other data sets published in the literature. Linear stepwise regression was then performed to better understand the relative strength of the 9 movement variables (coin lift; box lift; torsion control; right and left single leg squats; stand-sit-stand; stand, drop, stand; and right and left in-line lunges) to predict movement quality, described by the sum of the 9 movement test scores (Total Movement Score). The probability of variables to enter the model was $F \leqslant 0.05$ and the probability to exit was $F \geqslant 0.10$. Scores for the various torso endurance and strength measures were compared across 8 age groups, separated every 5 years (i.e. < 25, 25–29, 30–34, 35–39, 40–44, 44–49, 50–54, > 54) to assist comparison with other published data sets. Statistical significance for all tests was tested at both $p < 0.05$ and $p < 0.01$ levels.

Table 2
Means and standard deviations of scores of all tests. (Note: data from some participants was not collected on certain tasks)

	N	Mean	SD
Age	282	36.5	9.4
Height (cm)	279	179.3	8.4
Body mass (kg)	279	88.7	10.7
Waist (cm)	220	92.7	9.9
Hips (cm)	214	103.8	8.2
Coin lift	275	1.4	0.6
Box lift	276	2.2	0.5
Torsion control upper	275	1.4	0.6
Single leg squat (right leg)	275	1.8	0.6
Single leg squat (left leg)	275	1.8	0.6
Stand-sit-stand	277	2.3	0.5
Stand, drop, stand	272	2.3	0.7
In line lunge (right)	276	1.8	0.9
In line lunge (left)	276	1.9	0.8
Total movement score	282	16.3	3.6
Biering-sorensen (seconds)	224	86.5	36.0
Right side plank (seconds)	269	55.2	20.3
Left side plank (seconds)	268	55.3	20.1
Front plank (seconds)	275	129.1	53.0
Right grip strength (kg)	273	59.9	13.7
Left grip strength (kg)	273	58.0	12.8
Pull ups (repetitions)	271	6.3	5.1
Absolute magnitude of asymmetry between left and right hip ROM			
Hip extension – knee bent (degrees)	194	10.2	10.4
Hip extension – knee straight (degrees)	195	9.8	18.0
Hip flexion – knee bent (degrees)	194	7.5	7.0
Hip flexion – knee straight (degrees)	194	7.9	8.6

Descriptive comparisons of the means for measures of torso endurance and strength were made with other occupational groups deemed similar to the current population of firefighters (i.e. other firefighters, police officers and athletic populations) as well as members from the general population (i.e. healthy adult men and university students).

3. Results

Means and standard deviations for all tests are listed in Table 2. Analysis of the correlation scores revealed weak links between several variables (Table 3);

Table 3

Pearson moment correlations between variables scored with ratio scales and units. Only those correlations greater than 0.2 and that were significant at the 0.01 (**) levels are listed

		Age (years)	Height (cm)	Body mass (kg)	BMI (kg/m^2)	Waist Circumerence (cm)	Hip Circumference (cm)	Total movement score	Biering-sorensen (seconds)	Right side plank (seconds)	Left side plank (seconds)	Front plank (seconds)	Grip strength (right hand) (kg)	Grip strength (left hand) (kg)	Pull ups (repetitions)
Age (years)	R	1				0.287**									
	alpha					0.01									
Height (cm)	R		1	0.258**	−0.652**				−0.219**	−0.205**					
	alpha			0.01	0.01				0.01	0.01					
Body mass (kg)	R			1	0.417**	0.588**	0.506**	−0.239**	−0.264**	−0.346**	−0.377**	−0.302**			−0.316**
	alpha				0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01			0.01
BMI (kg/m^2)	R				1										
	alpha														
Waist circumer-ence (cm)	R					1	0.403**	−0.203**	−0.294**	−0.267**	−0.300**	−0.316**			−0.340**
	alpha						0.01	0.01	0.01	0.01	0.01	0.01			0.01
Hip circumfer-ence (cm)	R						1					−0.257**			
	alpha											0.01			
Total movement score	R							1	0.368**	0.223**	0.220**				0.293**
	alpha								0.01	0.01	0.01				0.01
Biering-sorensen (seconds)	R								1	0.406**	0.403**	0.242**			
	alpha									0.01	0.01	0.01			
Right side plank (seconds)	R									1	0.840**	0.412**			0.207**
	alpha										0.01	0.01			0.01
Left side plank (seconds)	R										1	0.391**			0.270**
	alpha											0.01			0.01
Front plank (seconds)	R											1			
	alpha														
Grip strength (right hand) (kg)	R												1	0.634**	0.485**
	alpha													0.01	0.01
Grip strength (left hand) (kg)	R													1	0.206**
	alpha														0.01
Pull ups (repetitions)	R														1
	alpha														

**Correlation is significant at the 0.01 level (2-tailed).

Table 4

a. Spearman rank order correlations between movement competency scores. Only those correlations greater than 0.2 and that were significant at the 0.01 (**) levels are listed

		Coin lift	Box lift	Torsion control	Single leg squat (right leg)	Single leg squat (left leg)	Stand-sit-stand	Stand, drop, stand	In-line lunge (right leg)	In-line lunge (left leg)	Total movement score
Coin lift	R	1.0									0.211**
	alpha										0.01
Box lift	R		1.0	0.293**	0.237**	0.203**	0.379**				0.490**
	alpha			0.01	0.01	0.01	0.01				0.01
Torsion control	R			1.0			0.347**	0.290**		0.248**	0.579**
	alpha			0.01	0.01		0.01	0.01			
Single leg squat (right leg)	R				1.0	0.718**	0.271**				0.502**
	alpha					0.01	0.01				0.01
Single leg squat (left leg)	R					1.0					0.439**
	alpha										0.01
Stand-sit-stand	R					1.0	0.240**				0.487**
	alpha						0.01				0.01
Stand, drop, stand	R						1.0			0.407**	
	alpha									0.01	
In-line lunge	R	1.0							0.836**	0.518**	
(right leg) alpha								0.01	0.01		
In-line Lunge (left leg)	R	1.0								0.565**	
	alpha									0.01	

**Correlation is significant at the 0.01 level (2-tailed).

although, in general the correlations could be considered low. Age was not linked with any fitness or movement competency variable. However, body mass and waist circumference were related ($p < 0.01$) to a lower Total Movement Score ($r = -0.24$ and $r = -0.20$, respectively). The Biering-Sorensen score was found to have the strongest relationship with the Total Movement Score in comparison to all other tests ($r = 0.37$). All torso endurance scores correlated negatively with body mass, but not BMI. Height was negatively related to side plank scores. Grip strength had no link to body size (i.e. height, body mass, BMI or waist and hip circumference), but it was related ($p < 0.05$) to the number of pull-ups performed. Hip ROM asymmetries (flexion or extension) were not related to any measures of anthropometrics, overall movement score, torso endurance or strength, and thus the correlations are not included in Table 3.

Interestingly, several relationships were found to exist amongst the various movement screening tasks (Tables 4a and 4b). For example, the coin lift (light load) was correlated with the Total Movement Score, though it was not related to any other movement task. Adding load to a similar task influenced the inter-task relationships as the box lift was correlated with 4 other movement tasks, with the stand-sit-stand having the strongest correlation ($r = 0.38$). The torsion control test was also linked to 4 other movement tasks, as well as with grip strength. Certain tasks such as the single leg squat, however, were found to better correlate with body mass, hip and waist circumference (negative), and torso endurance scores than the other movement tasks evaluated in this investigation. Surprisingly, squat competency was not linked with symmetry of hip ROM. The stand-sit-stand test was the only movement task that was related to hip asymmetry ($r = -0.20$, $p < 0.01$), in that more asymmetry caused poorer stand-sit-stand competency.

> *The following paragraph has been modified to address the reviewer's comment.*
> The five movement tasks found to best predict the Total Movement Score using a Linear stepwise regression resulted in the following equation: Total Movement Score = 2.04*right single leg squat + 2.02*left in-line lunge + 1.69*stand-sit-stand + 1.23*coin lift + 0.98*stand-drop to floor-stand + 1.48. These five test scores explained 78% of the variance in the total movement score ($p < 0.001$).

The firefighters' torso endurance and strength scores were compared with several other groups. Torso endurance comparisons (Table 5) were made with men and women varsity basketball and cross-country athletes [25], healthy men and women from a university

Table 4

b. Spearman rank order correlations between movement competency scores and all other variables. Only those correlations greater than 0.2 and that were significant at the 0.01 (**) levels are listed

		Age (years)	Height (cm)	Body mass (kg)	BMI (kg/m^2)	Waist circumerence (cm)	Hip circumference (cm)	Beiring-sorensen (seconds)	Right side plank (seconds)	Left side plank (seconds)	Front plank (seconds)	Grip strength (right hand) (kg)	Grip strength (left hand) (kg)	Pull ups (repetitions)
Box lift	R						−0.221**	0.223**				0.215**		0.211**
	alpha						0.01	0.01				0.01		0.01
Torsion control	R							0.366**				0.262**	0.273**	
	alpha							0.01				0.01	0.01	
Single leg squat (right leg)	R			−0.260**	−0.280**	−0.286**	−0.301**	0.252**	0.259**	0.238**	0.206**			0.311**
	alpha			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01			0.01
Single leg squat (left leg)	R			−0.287**	−0.276**	−0.370**	−0.316**	0.232**	0.253**					0.369**
	alpha			0.01	0.01	0.01	0.01	0.01	0.01					0.01
Stand-sit-stand	R							0.247**				0.246**	0.248**	
	alpha							0.01				0.01	0.01	
Stand, drop, stand	R													
	alpha													
In-line lunge (right leg)	R									0.219**				0.251**
	alpha									0.01				0.01
In-line lunge (left leg)	R									0.229**				0.250**
	alpha									0.01				0.01

**Correlation is significant at the 0.01 level (2-tailed).

Table 5
Comparison of the scores of the firefighters in this study contrasted with other groups. 'N' corresponds to the total number of participants in that age group; some participants in the current firefighter population did not participate in all tests

		Age	N	Torso endurance				Strength		
				BSE	Front plank	Right side plank	Left side plank	Grip strength R	Grip strength L	Pullups
Firefigthers of the current study	Male	< 25	19	101.1	111.3	53.3	53.2	58.4	56.4	9.2
		25–29	58	81.1	122.1	58.9	56.5	59.3	56.0	8.4
		30–34	62	89.0	129.9	53.8	54.3	61.8	60.2	9.0
		35–39	47	84.6	132.1	51.4	51.4	59.1	58.2	7.0
		40–44	29	81.6	125.9	51.9	53.2	57.2	55.7	4.9
		45–49	26	95.6	147.7	63.8	64.3	64.8	60.4	5.8
		50–54	28	77.4	130.9	57.3	61.1	58.7	58.5	4.4
		> 54	10	66.8	141.8	46.4	46.0	56.1	55.5	1.4
		All ages	279	84.6	130.2	54.6	55.0	59.4	57.6	6.3
*Emergency Police task Force	Male	< 35	16	105.2	154.4	85.4	78.8	51.6	51.3	12.1
		35–39	16	109.9	161.2	78.0	78.9	56.9	53.4	10.2
		40–44	16	108.8	177.4	88.8	85.8	46.9	49.9	6.8
		> 44	5	107.8	155.5	79.8	78.9	54.9	53.0	10.9
		All ages	53	107.9	144.0	73.1	77.1	58.6	55.3	11.7
†Athletes	Basketball (male)	19.0	44	131.4		82.7				
	Basketball (female)	19.1	60	115.7		57.8				
	Cross-contry (male)	19.0	17	122.9		87.6				
	Cross-contry (female)	19.1	18	151.4		60.9				
Students	‡Male		82	141.0	183.0	97.0	96.0			
	‡Female		99	155.0	106.0	69.0	68.0			
	§Male	23	31	146.0		94.0	97.0			
	§Female	23	44	189.0		72.0	77.0			
**General public	Male	25–34	24					52.5	49.5	
		35–44	34					52.0	51.0	
		45–54	37					51.0	49.5	
	All ages		95					51.8	50.0	
#Other firefighters	Male	20	127	125.5	135.0					
		30	270	116.5	136.0					
		40	138	114.5	147.5					
		50	125	104.5	131.0					
		average	660	115.3	137.4					
	Female	32.7	17	144.0	129.5					
††Chinese People's Armed Police Forces	Male	18.3	805					38.0		4.8

BSE – Bering-Sorensen Extension; *McGill et al. [30] – mean age: 37.8(5.0) years, height: 1.79(0.09) cm, body mass: 88.7(12.1) kg; †Leetun et al. [25] – mean age: 19.1(0.9) years, body mass: 78.8(13.3) kg; ‡McGill et al. [26] – firefighter mean age: 37.5, body mass: 89.2 kg; student mean age: 19 years, BMI: 26 kg/m^2; §McGill et al. [23] – mean age: 23(2.9) years; **Massy-Westropp et al. [27] – height and body mass not reported for the populations selected; ††Wang et al. [28] – mean age: 18.3(1.0) years, height: 170.4(5.3) cm, body mass: 62.5(8.8) kg.

community [23], men and women undergraduate students [26] and another group of firefighters [26]. Torso endurance times for the current firefighter population were lower than all other comparison groups, (in some cases approximately 40% lower back endurance) with the exception of the front plank score from a group of female students. Grip strength of the firefighters appears to be superior to those of the general public [27]. The same is true of their pull up repetitions compared to members of the Chinese People's Armed Police [28] (see Table 5).

4. Discussion

The questions asked in this study examining a data set obtained from active firefighters were unified around several themes: Can fitness variables predict movement competency, specifically, could fitness variables and personal characteristics, such as age, influence movement quality? The results supported the conclusion that age had much less to do with fitness and the ability to move well, at least until the age of 55 years, than body mass or other related measures like waist and hip circumference. This has substantial implications on the value of staying fit and efforts to encourage occupational fitness. The quality of movement has probably been underappreciated in traditional fitness testing given the apparent link between movement quality and its influence on the risk of injury. While this notion is well established for knee injury [14] it appears to be gaining more support for general injury [29]. The data of this study also supported the notion that predicting the quality of movement in one task was not well predicted by another task, particularly when the load changed. The implication of this relationship is that evaluations of movement may need to match the demands of the anticipated task, or at least be comprehensive enough to incorporate unconstrained movement, at different speeds, and under different loads. That stated, being generally fit, and not being heavy, appears to assist in achieving better movement. Further, if it turns out that better movement helps avoid future injury, or perhaps optimal recovery from injury if it occurs, then efforts to maintain both fitness and competent movement will be justified – time will tell with this cohort.

Limitations for interpreting the data of this study include the study population consisting of men who performed a relatively demanding job. While a large proportion of time is spent inactive, there are times of high exertion and danger. Thus results may have been different had a wide variety of people been studied who were engaged in a range of occupations, and perhaps possessing different fitness and movement skill. However, the data and general conclusion are quite similar to another study conducted on police officers [30].

Descriptive comparison of this data set with other groups suggests that the firefighters tested here were deficit in torso endurance but not in other measures. This may be important in that poor torso endurance, particularly lower back extension endurance, has been identified as having a link with elevated future back disorders [22] together with being associated with recurrent back episodes in those groups performing demanding work [9].

Other markers for injury have included joint asymmetry. For example, asymmetrical hamstring flexibility has been shown to predict future back injury over the careers of soldiers [13]. The data from the current study showed no link between hip asymmetry and the movement tasks chosen. One interpretation could be that while hip mobility may influence an individual's ROM, their movement patterns may be influenced by numerous factors, only one of which might be flexibility. Consider two individuals with similar hip mobility but different lifting patterns. Only one may have the awareness to move in a manner that is conducive to avoiding injury (e.g. using a hip hinge strategy) instead of lifting in a compromised position (e.g. such as with spine flexion which has been shown as a mechanism for back injury [31]). Movement may be an expression of stored movement patterns which would suggest the need to intervene on the movement pattern as well as traditional variables of fitness [32].

5. Conclusion

In conclusion, it appears that the ability for quality movement is not strongly correlated with traditionally utilized markers of fitness such as strength and endurance, nor is movement quality linked to other personal characteristics such as age at least in this population of active firefighters. Rather, being heavy with a larger waist circumference was related to a greater compromise of movement quality. This has implications for training in that simply training strength about a joint, or muscular endurance, may not enhance movement quality. Yet movement quality appears to be related to resilience for injury. Correspondingly, training movement would appear to be a necessary component of preparing for job or sport related readiness. As a note, this cohort of men was chosen for their employment stability. The intention is to follow their injury incidence and prevalence as they progress through their working careers to see which fitness variables and/or movement competency variables are protective against injury. It remains to be seen whether those with better movement quality will have fewer musculoskeletal injuries.

Ethics

This study has been reviewed by, and received ethics clearance through the Office of Research Ethics, University of Waterloo.

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