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Effects of Seated Load Carriage on Mobility

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Abstract

Research has determined significant health detriments associated with sitting for extended periods of time, including chronic disease risk, pain, and mobility. Additionally, although it is not researched commonly, sitting is an essential component of job related tasks for tactical professionals such as military, police and firefighters. **PURPOSE:** The purpose of this study was to determine if there is a relationship between seated load carriage and dynamic mobility. **METHODS:** Eighteen recreationally active Merrimack College Students (age: 23.33 +/- *1.45* yr) participated in the randomized, within groups, crossover study. All subjects completed a total of three study visits which consisted of a familiarization session, a seated load carriage session and an unloaded session. Directly before and after the seated portion of both sessions, subjects were assessed in the deep squat (DS), shoulder mobility (SM), and straight leg raise (SLR) from the Functional Movement Screen (FMS). **RESULTS:** There was no significant difference between pre- and post-sitting FMS score for any of the tests in the unloaded condition, or for the SLR and SM tests in the loaded condition. However, there was a significant difference between pre- and post-sitting for the DS ($P<0.05$) in the loaded condition. **CONCLUSION:** These results suggest that the use of a weighted vest may decrease ability to move through a full range of motion and therefore perform job tasks in a tactical profession. More research should be completed to confirm these findings in active duty tactical professionals and utilizing longer periods of sitting.

KEYWORDS: *Military, Load Carriage, Mobility*

Introduction

Review of Literature

Time spent sitting, or sedentary time, is an important consideration when assessing the health and well being of an individual. Extended sitting time has been associated with chronic diseases as well as pain and mobility in a range of populations (Fatima, Qamar, Hassan, & Basharat, 2017; Gupta et al., 2015; Katzmarzyk et al., 2009; Marshall, Mannion, & Murphy, 2009; Halbertsma et al., 2001). Extended sitting time is most commonly researched in populations such as office workers or students, but rarely in tactical professional populations, even though sitting is prevalent in those lines of work (Anderson, Plecas, & Segger, 2001). The addition of load carriage from weighted vests, rucksacks, helmets or other job related gear in these populations may decrease mobility to a greater extent than extended sitting without an additional load. The research to this point; however, has focused on biomechanical changes related to load carriage during physical activity as opposed to sitting (Ramstrand, Zügner, Larsen, & Tranberg, 2016). Finally, mobility can be assessed using a range of assessment tools. A common assessment for dynamic mobility is the Functional Movement Screen (FMS) which has been shown as a valid and reliable tool in the assessment of functional mobility across various populations including athletes, general populations, children and tactical professionals (Cuchna, Hoch, & Hoch, 2016). To the authors knowledge, this is the first study to examine FMS as it relates to change in mobility from extended sitting time.

Extended sedentary time has been linked to various chronic health conditions through research (Fatima et al., 2017; Gupta et al., 2015; Katzmarzyk et al., 2009; Marshall et al., 2009; Halbertsma et al., 2001). Such studies have found a dose-response relationship between increased time seated and all-cause mortality. Relatedly, other research has demonstrated strong evidence of a dose-response relationship between cardiorespiratory health and physical activity. Additionally, extended periods of sedentary time have been linked to increased levels of obesity, decreased energy and poorer quality of life (Katzmarzyk et al., 2009; Riebe et al., 2018).

Relatedly, extended seated time has been shown to decrease mobility and range of motion in individuals which may cause issues related to functional ability and musculoskeletal injuries. One such study determined difference in hip and hamstring mobility before and after an extended seated period in students (Fatima et al., 2017). Extended sitting was shown to have significant negative effects on hamstring mobility. Participants in the study displayed decreases of up to 15 degrees from pre- to post-sitting in the straight leg raise test from the Functional Movement Screen (Fatima et al., 2017). Secondarily, associations have been seen between increased hours of time sitting and low back pain intensity (Gupta et al., 2015). Previous research has indicated that low back pain may be partially a result of decreased hamstring and pelvic mobility due to muscle tightness. Researchers believe that the tightness of hamstrings may contribute to low back pain primarily because of the impact it has on posture and pelvic alignment (Marshall et al., 2009; Halbertsma et al., 2001).

Many of the previously mentioned studies discussed seated time as it relates to blue collar jobs and students; however, not related to tactical professions. Sitting was classified as a "very necessary" component of police work, where more than half of each shift was spent sitting in a study on police job task requirements (Anderson et al., 2001). The total average seated time for the participants was 373 min per shift. The sitting for police work can be associated with desk work in which officers are in the station, or extended sitting in a cruiser for a stake out or to monitor road safety (Anderson et al., 2001). Additionally, in military job task requirements, it is known that all branches of military will spend time sitting as it relates to individual missions. Such missions may include convoy operations or sitting in tanks for extended periods of time. With sitting being such a necessary component, the effects of sitting in tactical professions should be further investigated.

In addition to sitting, load carriage is an essential component of work in tactical professions such as police, military, or firefighters. Police carry the load of body armor and a firearm, while firefighters need to don personal protective equipment. Military personnel may carry loads as high as 68 kg with protective equipment, rucksacks and armor depending on the branch and the combat specialty (Carlton & Orr, 2014; Rodriguez et al., 2013). In 2015, the national average for military load carriage was 45.5 kg (Boynton, Park, & Neugebauer, 2017). Additionally, military police protective vests can weigh as high as 27 kg depending on sex, body size and specialty (Carlton & Orr, 2014). Active duty police have a wide variation in the load carried based on the department and the specific requirements for an assigned task. In general, the police will carry loads distributed between the waist belt which usually contains a pistol, ammunition, pepper spray, handcuffs, baton and radio along with a protective vest with ballistic plates (Ramstrand et al., 2016).

Specific biomechanical changes occur from load carriage in tactical professions based on the type of load carried and the location on the body. For military populations, it is very common the the majority of the weight carried is located on the soldier's back (Boynton et al., 2017; Seay, 2015). Posteriorly located load is associated with a large amount the biomechanical changes that may be associated with low back pain and decreased mobility. Firstly, the posterior location of the rucksack alters the soldier's center of mass from a central position, to a forward tilt. This is likely due to the need to transfer the weight over their base of support and increase stability. This forward lean may create increased motor unit firing rates in both the hip and low back musculature (Boynton et al., 2017; Seay, 2015). It is reasonable to assume that the increased load on the hip and low back may cause fatigue in those areas, with extended wear. The fatigue could lead to improper muscle control and injury or reduced mobility in the affected areas and the antagonist muscle groups.

Loaded vests in police have been shown to lead to biomechanical alterations such as reduced trunk, pelvis and hip range of motion even after the vests were removed (Ramstrand et al., 2016). As the police subjects in the study became more familiar with the vests over time; however, there was a reduction in the degree of biomechanical changes. Finally, the study demonstrated that police were limited in range of motion while wearing the vests, specifically in the upper body. The researchers found that when loaded, the officers were forced to walk with their arms in an abducted position (Ramstrand et al., 2016). The study suggested the need for more mobility assessments in police related load carriage. The shoulder and hip ROM impairments could be related to mobility decreases which may affect job performance. It also may be important to assess mobility and range of motion in different planes of movement or related to different job tasks such as sitting for extended periods of time (Ramstrand et al., 2016).

As noted, previous research has used various methods for assessing mobility in subjects. One of the common methods utilized throughout the research is the Functional Movement Screen (FMS). The FMS is a set of standardized protocols with a simple grading system that analyzes movement and mobility patterns in athletes and general population (Cook, 2010). The test includes seven individual tests and two clearance tests in total, however research has used individual components of the tests when assessing specific mobility aspects (Fatima et al., 2017; McGill et al., 2013). The FMS was initially developed as a tool for assessment in athletes to determine dynamic mobility and risk for injury, however it has been applied to a variety of other populations throughout research and development (Cook, 2010). Such populations include general populations, individuals recovering from injury, older individuals, children, and tactical professionals.

When addressing tactical professionals, FMS has been utilized to assess soldiers in various capacities. One study was conducted on Marine Corps officer candidates in order to determine if FMS scores could be predictive of injury in the population (Lisman, O'Connor, Deuster, & Knapik, 2013). The results indicated that low FMS scores had a strong association with injury in the subjects. The researchers concluded that based on the results, FMS may be a useful tool in assessing military populations fitness and risk for injury (Lisman et al., 2013). Another research study found that mobility and movement competency were significantly related to both job performance and injury risk in emergency task force police officers (McGill et al., 2013). This study conducted various fitness and mobility tests including components of the FMS. The researchers determined that officers with decreased mobility from the FMS and other testing scores were at increased risk of low back pain and other job related injury (McGill et al., 2013).

Purpose

Research has determined significant health detriments related to sitting for extended periods of time, including chronic disease risk, pain, and mobility. Additionally, although it is not researched commonly, sitting is an essential component of job related tasks for tactical professionals such as military, police and firefighters. With the addition of carried loads in the forms of weighted vests, helmets, loaded waist vests, rucksacks, and more, tactical professionals may be a greater risk of the negative effects of sitting during their work periods. Specifically, biomechanical adjustments from combined sitting and load carriage may significantly decrease dynamic mobility and range of motion. The FMS is a common tool utilized to assess dynamic mobility across a range of populations including military and other tactical professions. Thus, the purpose of this study was to determine if there is a relationship between seated load carriage and dynamic mobility in Merrimack College Students.

Methods

Experimental Design

The study was a randomized, within groups, crossover study examining the effect of seated load carriage on mobility utilizing FMS protocols. Over the course of the study, subjects spent a total of 3 sessions in the lab for one familiarization and two testing sessions. Each subject participated in both a loaded and unloaded testing session in a randomized order.

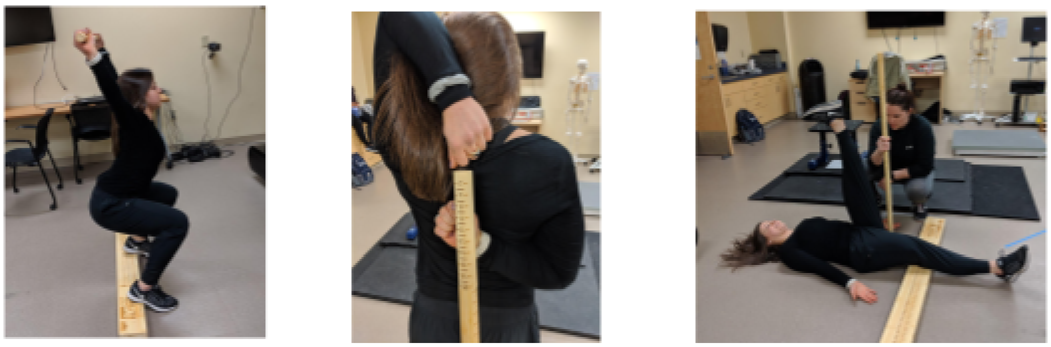
Familiarization and descriptive data collection. Prior to participating in the study, subjects attended a familiarization session, where they had the opportunity to ask the researcher clarifying questions before beginning research. Subjects were then familiarized with all testing procedures. Familiarization occured by the researcher explaining each procedure, followed by the subject practicing each procedure and being able to ask questions or voice concerns. Anthropometric data was then collected including height, weight, and body fat percentage using air displacement plethysmography (BodPod). Finally, subjects filled out a lifestyle questionnaire to determine physical activity habits, and alcohol, coffee, cigarette and e-cigarette consumption (Appendix A).

Loaded and unloaded session. The loaded session consisted of 1 hr of constant sitting time. During the loaded session, the subjects wore a 35 lb weighted tactical vest and sat on a 55 cm tall bench in the laboratory space. During the unloaded session, the subjects sat on the same bench without the 35 lb vest. FMS testing was conducted before and after sitting for both sessions. The vest was not put on until after FMS testing and removed before the FMS testing for the loaded session.

Figure 1. Subject Seated with 35 lb load

Functional movement screen. The FMS is a set of standardized protocols with a simple grading system that analyze movement and mobility patterns in athletes and the general population (Cook, 2010). For the purposes of this study, the deep squat (DS) shoulder mobility (SM), and straight leg raise (SLR) tests were used. For each test, subjects were assigned a score between 0 and 3. A score of 0 represented the subject experiencing pain resulting in test termination, and a score of 3 references execution with no complications or modifications. For each test the subjects were allowed to repeat the movement 3 times if a perfect score was not achieved on the first try. For the SM and SLR test, the lowest of the raw scores was taken for statistical analysis. For more detail regarding scoring and the individual procedures, see Appendix B.

Figure 2. Functional Movement Screen Images



Deep Squat Shoulder Mobility Straight Leg Raise

Participants

Participants were recreationally active students at Merrimack College. Recreationally active was defined as non-athletes who exercise for at least 150 min per week. Eighteen male and female graduate students were recruited and completed all of the testing requirements. Subjects had no history of musculoskeletal injury or concussion in the last 6 months. This study was approved by the Merrimack College Institutional Review Board.

Table 1

Descriptive Statistics of Subjects (n=18)

Test	*Mean*	*SD*
Age (yr)	23	±1.5
Height (cm)	169.9	±8.2
Weight (kg)	79.9	±17.1
Body Fat (%)	24.0	±8.8

Statistical Analysis

Statistics were analyzed using the IBM Statistical Package for the Social Sciences (SPSS). A paired t-test was used to compare the mean values for pre- and post-sitting FMS scores. The t-test was also used to determine if there was a significant difference between the means for pre- and post-sitting for the loaded condition versus pre- and post-sitting for the unloaded condition. Statistical significance was set at $P<0.05$.

Results

There were no significant change from pre- to post-sitting FMS scores for any of the tests in the unloaded condition. Additionally, there were no significant differences between pre- and post-sitting FMS scores for both the SLR and SM tests in the loaded condition. There was a significant decrease from pre- to post-sitting for the DS ($P<0.05$) in the loaded condition. Additionally, there was a significantly lower pre-sitting SM score for the unloaded condition then the loaded condition.

Table 2

Pre- and Post- Sitting FMS Scores

	Pre-Sitting		Post-Sitting	
	Mean	*SD*	*Mean*	*SD*
Loaded Straight Leg Raise	2.78	±0.548	2.72	±0.669
Unloaded Straight Leg Raise	2.78	±0.548	2.78	±0.548
Loaded Shoulder Mobility	2.50	±0.618	2.39	±0.778
Unloaded Shoulder Mobility	2.28**	±0.826	2.17	±0.924
Loaded Deep Squat	2.50	±0.514	2.39*	±0.383
Unloaded Deep Squat	2.39	±0.502	2.33	±0.485

*Indicates a significant difference between pre- and post-sitting ($P<0.05$)

** Indicates a significant difference between the loaded and unloaded conditions ($P<0.05$)

Discussion

The purpose of this study was to determine if there is a relationship between seated load carriage and dynamic mobility in Merrimack College Students. Most of the results displayed no significant differences between pre- and post-seated FMS score for both the unloaded and loaded conditions. There was a significant difference; however, between pre- and post-sitting for the DS test in the loaded condition. To the authors knowledge this is the first study to combine the effects of extended sitting and load carriage on mobility.

Extended sitting time has been linked across research to a multitude of chronic health issues and decreased mobility (Fatima et al., 2017; Gupta et al., 2015; Halbertsma et al., 2001; Katzmarzyk et al., 2009; Marshall et al., 2009). Additionally, sitting for extended periods of time has also demonstrated significantly higher compressive loads in the low back when compared to standing (Callaghan & McGill, 2001). As expected, the study displayed no significant change in mobility before and after sitting when the subjects were unloaded, which is likely due to the length of time seated being one hour. The authors hypothesized that the unloaded condition would create no significant changes in mobility because all studies with significant change from unloaded sitting lasted six or more hours (Marshall et al., 2009; Halbertsma et al., 2001).

When combined with the 35 lb load, the mean score of the DS decreased significantly, although none of the other FMS test scores did. This is likely because out of the three tests utilized, the DS is the one that specifically addresses hip, trunk, and pelvis range of motion as well as postural control (Cook, 2010). Load carriage in tactical populations has been associated with biomechanical changes such as excessive forward trunk lean and reductions in hip, trunk and pelvis range of motion both during and after load carriage (Boynton et al., 2017; Ramstrand et al., 2016; Seay, 2015). Additionally, extended time sitting has been shown to create increased compressive forces on the low back, which increases activation of core musculature (Callaghan & McGill, 2001). In this study, the addition of load, coupled with an extended sitting period, may have increased the need for that core musculature activation. Consequently, the increased activation of core musculature may have led to a development of fatigue, causing the subject to be unable to perform the DS test as effectively post-sitting with load. Future research combing load carriage and sitting could address this theory by including electromyogram readings in core musculature throughout the testing and the time seated.

Additionally, there was not a significant change in mean SLR score from both loaded and unloaded sitting. Previous research; however, has found a connection between increased sitting time, decreased hamstring mobility, and low back pain even when no load carriage was added (Marshall et al., 2009; Halbertsma et al., 2001). The author hypothesized that the addition of the 35 lb vest in this study would result in a greater decrease in hamstring mobility as measured by the SLR test. This may not have been the case because the seated period in this study was one hour, while the periods utilized in the previous studies ranged from 6-8 hours in unloaded conditions (Marshall et al., 2009; Halbertsma et al., 2001). There is potential that seated load carriage would create a decrease in mobility sooner than six hours due to the increased load. Further research should investigate varying lengths of time seated with load to determine at what point mobility, as assessed by the SLR, is decreased significantly.

When SM was addressed, there was no significant difference between the mean scores for pre- and post-sitting for either the loaded or unloaded condition. There was a significant difference; however, when comparing the means for the pre-sitting SM scores for the loaded and unloaded condition. It is unknown to the author why this occurred; however, because the FMS has been proven to be a reliable clinical assessment across recent literature (Cuchna, et al., 2016). Although participants were instructed to avoid strenuous exercise 48 hr prior to testing, it is possible that they did not adequately rest enough which may have affected mobility in the upper body. Additionally, participants may have underreported any injuries incurred between testing sessions for fear of being eliminated from the study. Additionally, with the use of the FMS shoulder mobility exam, the score is limited to a zero to three scale. If on day one of testing, the subjects were within one hand length, they would receive a score of 3. However, if on day two they were just 1 cm outside of that length, the score instantly dropped to a 2. This could explain the significant difference between conditions. It is possible that if the researcher had recorded centimeters instead of FMS score, the difference may not have been as significant.

Practically, the combined effect of sitting and load carriage should be acknowledged as potentially harmful to individuals health and also performance of tasks related to tactical professions. When possible, superiors in tactical settings should encourage individuals who have been sitting for a bout of time to get up and move. It may also be important for tactical strength and conditioning specialists to consider the effects of seated load carriage when conducting a needs analysis for tactical athletes. Strength programs for these athletes should include exercises such as anti-flexion, anti-rotation, or anti-rotation core stability work in order to aid in the reduction of the excessive forward trunk lean and improve postural control. Additional attention should also be paid to addressing the decreased range of motion in the hips and pelvis by implementing stretches and mobility exercises that specifically target those regions. Previous research has examined the effect of such core strengthening programs on load carriage performance measures and back pain and mobility issues across a range of populations with some success (Akuthota, Ferreiro, Moore, & Fredericson, 2008; Hoppes et al., 2016; Stuber, Bruno, Sajko, & Hayden, 2014).

Previous research has utilized the FMS in tactical populations primarily as a tool to predict injury risk and job performance (Lisman et al., 2013; McGill et al., 2013). Additionally, the FMS has been proven to be a reliable test when assessing mobility and functional movement across a range of populations; however, this may be the first study to utilize the test to assess the relationship between seated load carriage and mobility. Although previous research has proven the effectiveness of the FMS tests for assessing dynamic mobility, and predicting injury risk in tactical populations, it may not show smaller changes due to the scoring system (Cook, 2010; Lisman et al., 2013; McGill et al., 2013). Further research could address this limitation by comparing the FMS with different modes to assess dynamic mobility before and after sitting with the load.

Conclusion

The results of the current study demonstrate a significant change in dynamic mobility assessed by the FMS deep squat test as a result of extended sitting while wearing a 35 lb load. The results suggest that the use of a weighted vest may decrease ability to move and therefore perform job tasks in a tactical profession. Due to the results seen in Merrimack College Graduate Students, further research in this area should be expanded to actual tactical professionals utilizing loads consistent with every day job tasks in order to confirm these results for this population. Although this study investigated the effects of a one hour seated load carry, further research should be done to investigate longer periods of sitting and whether or not there are chronic maladaptations to seated load carriage. Additionally, a study comparing male and female differences in relationship to seated load carriage may yield different results.

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Appendix A. Pre-participation Questionnaire

Subject #:________________ Sex: ________ DOB: _____________

Health History:

Do you have any history of the following? (Check all that apply)

__ Musculoskeletal injury in the past 6 months?

__ Concussion in the past 12 months?

__ Neurological disorder affecting vision or balance?

__ History of epilepsy?

__ Currently pregnant?

__ Pain or discomfort during extended periods of sitting

__ Low back pain

__ Shortness of breath or dizziness at rest

__ High blood pressure

Lifestyle:

In general, how often do you exercise weekly? (Circle one)

< 60 minutes 60-119 minutes 120-149 minutes ≥ 150 minutes

How long have you been consistently exercising for? (Circle one)

< 1 year 1-2 years 3-5 years > 5 years

What type of exercise activities have you participated in? (Circle all that apply)

Weight Training Cardio Group Exercise Classes Recreational Sport

High School Athletics College Sports Team Other

Do you take pre-workout supplements? (Circle one) Yes No

If so, how often and what type? ____

Do you smoke? (Circle one) Yes No

If so, how often? ____

Do you chew tobacco? (Circle one) Yes No

If so, how often? ____

Do you drink alcohol? (Circle one) Yes No

If so, how often? ____

Do you drink coffee or energy drinks? (Circle one) Yes No

If so, how often and what type? ____

Are you currently on any medications? (Circle one) Yes No

If so, what are they? ____

Other:

Is there anything else you would like us to know?

____

____

____.

Appendix B. Descriptions of Selected FMS Protocols

Deep squat.

For the DS, subjects will be instructed to stand with feet aligned in the sagittal plane at hip distance apart. They then press a dowell from 90° bent elbow to an overhead position. At this point the subject will be instructed to sink into the deepest squat possible. A score of 3 is earned if the subject can complete the squat while maintaining a stable core, keeping the heels on the ground, and avoiding knee movement in the transverse plane. If the subject cannot achieve a 3, they will be instructed to elevate heels on the FMS box and try again for a score of 2. If the subject is still unable to maintain stability, a score of 1 is assigned (Cook, 2010).

Shoulder mobility.

For the SM test, researchers will begin by determining the hand length of the subject's right hand from the distal wrist crease to the end of the longest finger. Next the client will be instructed to make a thumbs-inside-fingers fist with both hands before simultaneously reaching one fist behind the neck and the other around the back. Subjects should maintain the fists and move the hands in one, swift motion, and hold them in place. The researcher then measures the distance between the subject's hands. The top hand is assigned a score and then the subject will be asked to repeat the action on the other side. A score of 3 will be assigned if subject's reach distance is within a single hand length. Scores of 2 or 1 are assigned if the subject's hand reach is within 1.5 hand lengths or greater than 1.5 hand lengths, respectively (Cook, 2010). Scores for both the right and left shoulder will be recorded.

Straight leg raise.

For the SLR, the subject should begin laying supine, with palms up and knees over the FMS box. The researcher then needs to determine the midpoint between the anterior superior iliac spine (ASIS) and the knee joint and place the dowell vertically at that position. Next the subject will be instructed to lift the right leg. If the subject's malleolus successfully passes the vertical dowell, while maintaining a flexed foot and contact of the left knee to the board, a score of 3 will be assigned for the leg. If not, the researcher will move the dowel to a point a third of the way from the knee joint to the ASIS and the subject will try again. If the subject's malleolus successfully passes the dowell in this position, a score of 2 will be assigned. If the subject is unable to achieve either position, a score of 1 will be assigned (Cook, 2010). After the right leg is scored, the test will be repeated on the left leg and both scores will be recorded.