8-25-2016

The Reliability and Predictive Ability of the Movement Competency Screen in a Military Population

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thesportjournal.org/article/the-reliability-and-predictive-ability-of-the-movement-competency-screen-in-a-military-population/

U.S. Sports Academy August 25, 2016

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ABSTRACT:
Purpose: Musculoskeletal injuries in the United States Armed Forces impacts operational readiness. Therefore, a reliable, valid screening tool that identifies injury risk and predicts performance is needed. The purpose of this study was to: (1) establish the intra- and inter-rater reliability of the Movement Competency Screen (MCS) using a cohort of United States Naval Academy fourth class Midshipmen, (2) identify if a correlation exists between average total MCS scores and injury rates during training, and (3) identify if a correlation exists between

average total MCS score and performance on the Physical Readiness Test (PRT).

Methods: Five raters independently evaluated 41 digital recordings of subjects who performed the MCS. An intraclass correlation (ICC) of 0.9 (95% CI) was used to determine raters' reliability and a Spearman's Correlation Coefficient examined relationships between average initial total MCS score with both (1) injury data and (2) PRT scores.

Results: Raters demonstrated good inter-rater reliability (ICC = 0.88, 95% CI: 0.81-0.93), and moderate to good intra-rater reliability (ICC = 0.63-0.89) for total MCS scores. The average total MCS scores did not correlate with the total number of injuries sustained. However, a moderate positive correlation (r = 0.48; p = 0.003) was observed between average total MCS score and overall PRT scores for all subjects. For only female subjects, a very strong correlation was observed between average total MCS score and (1) overall PRT scores (r = 0.83; p = 0.00), (2) increased number of push-ups (r = 0.76; p = 0.001), and (3) slower run-times (r = – 0.84; p = 0.00). These relationships were non-significant for male subjects.

Conclusions: The high reliability reported is similar to Reid et al. 2015. The initial MCS score correlates with PRT performance for female subjects, but not males. However, the MCS score did not predict injury incidence in this cohort.

Practical Application: Given the high reliability, the MCS may be a useful screening tool for the U.S. Armed Forces to identify recruits with poor movement competency, likely impacting poor performance on the PRT. Future research will examine the relationship, if present, between total MCS score and injury risk in this cohort.

Key Words: reliability, mass screening, United States Armed Forces, military, movement competency, musculoskeletal injury, performance

INTRODUCTION

The annual incidence of musculoskeletal injuries sustained in the United States Armed Forces has a significant impact on military capacity (10, 20, 25). Overuse injuries are the cause for 70-84% of musculoskeletal injuries sustained by military personnel in combat and training settings (8, 26). Overuse injuries account for 4.8 million out of 11 million annual limited duty days (28). Of concern is that 39-49% of these overuse injuries are localized to the lower extremity and are commonly due to modifiable training variables such as improper exercise technique and inadequate training preparation (8, 10). The cost of discharging a soldier from military training is approximately $57,500 per individual and 80% of the disability-related medical discharges for first year military recruits are the result of musculoskeletal injuries. Thus, the large volume of musculoskeletal injuries presents a significant financial burden to the military as these injuries are associated with missed training days, large rehabilitation costs, and decreased combat readiness (18).

The Movement Competency Screen

Due to the detrimental effect of musculoskeletal injuries on the military's effectiveness, establishing a screening method to identify injury risk factors, in military recruits, prior to the initiation of training is crucial (26). A new screening tool, the Movement Competency Screen

(MCS), has the potential to be used to identify risk factors in the military population (22). The MCS is designed to evaluate an athlete's ability to properly perform a series of seven controlled movements under a body weight load (13). The seven movements (squat, lunge, twist, bend, pull, push-up, and single leg squat) are scored based on the presence of faulty movement patterns in body segments referred to as primary or secondary impairments. Impairments identified in each movement task are totaled in order to assign a load level (1, 2, or 3) for that task. The summation of load levels results in the total MCS score, ranging from 7 to 21 (13). Based on the designated total MCS score, athletes are categorized as having "poor" (7-10), "moderate" (11-16) or "good" (17-21) movement competency.

The MCS differs from other movement screens, such as the Functional Movement Screen (FMS), because the MCS is scored through analysis of digital recordings and employs more stringent scoring criteria specific to each body segment. Given that the intra- and inter-rater reliability of a screening tool increases with videotape/digital recording analysis compared to real-time analysis (2, 24), the MCS has an advantage over the FMS as its reliability may be enhanced because clinicians can view the athletes' movements repeatedly. In fact, Reid et al. (22) have demonstrated high intra- and inter-rater reliability of the MCS in high school netballers who underwent the Netball Movement Screening Tool, a component of which was the MCS. However, the reliability of the MCS has yet to be established in other populations. Due to the increased risk for injury amongst military personnel, it is important to determine the reliability of the MCS in this population, in the hopes of more efficiently identifying modifiable risk factors of injury.

Injury Rates

An individual's movement patterns dictate the way their muscles and joints are loaded during exertion, thereby influencing power output and potential injury risk (13). Current literature shows a relationship between movement dysfunction and the risk for the development of injuries (5-7, 13, 16, 24-26). Additionally, a limited selection of studies reports associated relationships between lower scores on the FMS, reflecting poor movement performance and increased injury risk in athletic populations (2, 11, 17, 21). However, to date, no movement screen, including the FMS or MCS, has been shown to be capable of identifying injury risk in military subjects. Due to the limited predictive ability of the available screening tools, the military has attempted to correlate injury risk with entry-level fitness status (16, 17). To do so, the military uses the physical training programs which provide recruits with specific training principles aimed at increasing physical fitness, and thereby, decreasing injury rates (16). It has been shown that self-reported lower fitness levels strongly correlate to future injury risk (1, 12, 17). However, such strategies do not allow for individual recruits to be pre-screened prior to training; yet individual military recruits are continually mandated to participate in a high-intensity training program, increasing an individual's risk of injury. The MCS is designed for use prior to training program initiation in order to identify movement dysfunction that may place an individual at risk for injury. Based on this principle, the MCS may effectively fill the void, in the military, to predict injuries in this population.

Physical Readiness Test Results

Standardized movement screening should not only identify individuals likely to be at risk for developing a musculoskeletal injury but it should also differentiate those individuals who are in need of specific targeted training to enhance their physical performance. In the interest of resource conservation, a screen that predicts injury, as well as identifies individuals in need of additional physical fitness training prior to entry into a basic training regime, would be beneficial given that inadequate fitness levels is a modifiable risk factor of musculoskeletal injury development. Movement screens, such as the MCS, attempt to identify efficient movement patterns based on the premise that the higher an individual scores on a movement screen, the closer the individual is to meeting the biomechanical criteria for healthy and efficient movement patterns (10, 20, 26). Thus, the MCS offers the military a strategy for screening individuals to predict those who will perform poorly on the Physical Readiness Test (PRT) and need additional remediation in order to meet physical performance standards. Expediting the assessment process will target individuals in need of intervention earlier in their military training program, with the goal of preventing the development of injuries and reducing rehabilitation costs in the future.

Research Aim

The purpose of this study was threefold: (1) establish the intra- and inter-rater reliability of the MCS using a cohort of United States Naval Academy (USNA) fourth class (4/C) Midshipmen, (2) identify if a correlation exists between average total MCS score and injury rates during training, and (3) identify if a correlation exists between average total MCS score and performance on the PRT in this same cohort. We hypothesized that the MCS will demonstrate both high intra- and inter-rater reliability, and that lower average total MCS scores will correlate with increased incidence of musculoskeletal injuries as well as with decreased overall performance on the PRT.

METHODS

Subjects

A convenience sample of United States Naval Academy (USNA) 4/C Midshipmen subjects was used in this study. Subjects (n=41; 15 females, 26 males) were videotaped while performing the MCS at USNA. USNA provided the videotapes to the University of Vermont (UVM) for data analysis (CHRMS: 15-212). To protect subject identity, videos were standardized by having the participants wear masks and official USNA apparel (i.e., matching tee shirts and shorts). The rights of the subjects were protected in accordance with all federal regulations and subjects had the study explained to them with adequate time for questions and an opportunity to withdraw from the study at any time without consequence. All subjects signed a lay summary and consent form (USNA.2014.0016-IR-EPR-A) and all records have been kept confidential in accordance with all federal regulations.

Raters and Training Procedure

Five raters were trained on the scoring criteria for the MCS. Four raters were second year Doctor of Physical Therapy students and the fifth rater had 33 years of experience as a physical therapist. However, all raters were considered novices to the MCS. Prior to undertaking this study, the raters had 40 hours of training on the MCS. Training methods included group discussion regarding scoring criteria and its application to ratings of videos. Raters viewed and discussed videos in which subjects exhibited various movement impairments, until raters reached a consensus about observations. After initial group analysis, raters evaluated five pilot videos twice in one ten week period and evaluated 11 videos during an additional three-week period, all followed by group discussion to reconcile observational differences. Lastly, raters performed a pre-reliability analysis prior to initiation of this study (n = 10 videos) with good reliability. Reliability was calculated using a one-sided intraclass correlation coefficient (ICC) of 0.9 (95% CI) based upon absolute agreement.

Rating Protocol

Using the nQuery Advisor statistics tool, we determined that 41 videos were required to reach a one-sided ICC of 0.9 (95% CI) in order to determine inter- and intra-rater reliability. The five raters were blinded to others' scores by: placing barriers between rating stations, prohibiting the viewing of the same video simultaneously, storing the raters' score sheets separately, and prohibiting any verbal communication about individual subjects and/or ratings. A maximum of five videos per day was permitted, each with unlimited replay.

Scoring Criteria

Subjects performed three successive trials of each of the seven movements (captured from the anterior and both lateral views via digital recording). The lunge and twist, though performed together, are scored as two independent tasks. Similarly, the bend and pull is performed as one fluid movement but are scored separately. Raters determined the load levels (1, 2, or 3) for each of the seven movements based on the combination of impairments present (or absent) during a single movement (Appendix 1). For all seven movements, raters evaluated the lumbar spine for the presence or absence of any primary impairment. Raters also evaluated three of the following body regions for the seven movement tasks: shoulders, hips, depth, ankles/feet, head, and balance. Load levels, determined by the combination of the presence/absence of any movement impairment in any body region across the seven movements, were summed to calculate the total MCS score (7-21). Based on the designated total MCS score, subjects were categorized as having “poor” (7-10), “moderate” (11-16) or “good” (17-21) movement competency.

Injury Data Collection

Medical reports detailing injuries sustained by individuals, within the cohort, during service training, within the academic year were collected at USNA, de-identified and then shared with UVM personnel in order to examine the relationship between MCS score and reported injury data and training days missed. Raters manually classified injury data into categories by body region, body segment, and injury type, in accordance with categories put forth in current literature (10). Training days missed were calculated by subtracting the return to training date from the onset of injury date per injury plus one day.

Performance Data Collection

PRTs were administered at USNA and de-identified results from the Fall 2014 and Spring 2015 academic semesters were shared with UVM personnel for examination of the relationship between the total MCS score and PRT performance. Performance results were verified utilizing an algorithm written by USNA and composite PRT scores were calculated from the individual component parts of the test (i.e., 2-min curl-ups, 2-min push-ups, and 1.5 mile run).

Statistical Analysis

The intra- and inter-rater reliability of the total MCS score was computed using a one-sided ICC of 0.9 (95% CI) based upon absolute agreement. To establish rater agreement on the assigned load level, a distribution proportion was used and established that at least three out of five raters (60% agreement) had to assign the same load level. Percent agreement was used to evaluate rater agreement on the presence/absence of primary impairments for each of the seven individual movements. A Spearman's Correlation Coefficient was used to determine the relationship between the total average MCS score and the following variables: total incidence of injury, total incidence of injury by body region, total number of days off from training duties, overall PRT score, number of curl-ups performed in two minutes, number of push-ups performed in two minutes, and the total time it took for an individual to run 1.5 miles. A p-value of 0.05 was used to determine statistical significance.

RESULTS

Total MCS Score

Raters demonstrated good inter-rater reliability (ICC = 0.878, 95% CI: 0.808-0.928) when assigning the total MCS score across subjects (n = 41). The average total MCS score assigned to the males (n = 26) and females (n = 15) was 12.28 (S.D. ±1.61) and 11.22 (S.D. ±1.79), respectively. Total MCS scores ranged from 7-18, with the majority of subjects falling in the "moderate" or "poor" category for movement competency (Figure 1). Four out of the five raters achieved good intra-rater reliability (Rater 1: ICC = 0.889; Rater 3: ICC = 0.837; Rater 4: ICC = 0.885; Rater 5: ICC = 0.875). One rater demonstrated moderate intra-rater reliability (Rater 2: ICC = 0.631).

Figure 1. Total MCS Score by Rater and Movement Competency

Load Level

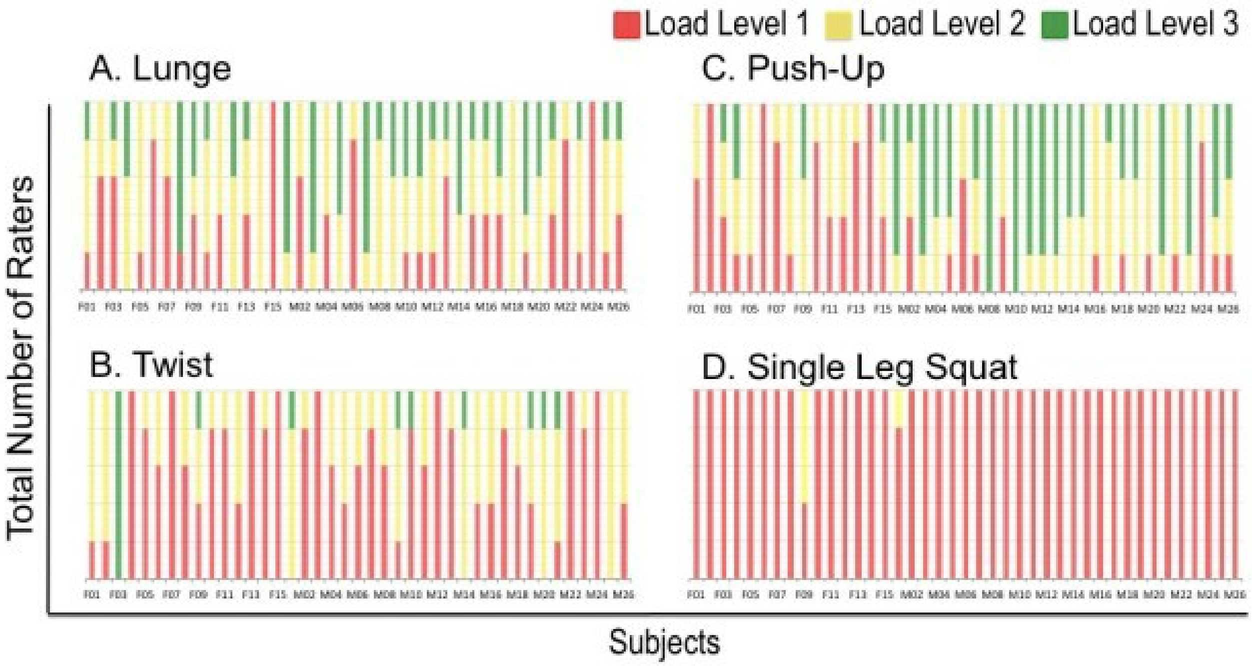
In general, raters demonstrated higher agreement when assigning load level for movements primarily evaluating the lower extremity and trunk, and lower agreement when assigning load level for movements evaluating the upper extremity as determined by the distribution proportion. Raters reached highest agreement on load level for four of the seven total MCS movements (squat, twist, bend, and single leg squat) (Table 1). In contrast, raters reached the lowest agreement on load level for the pull (agreement on only 34 of 41 subjects by 3 of 5 raters), the push-up (33 of 41 subjects), and the lunge (32 of 41 subjects) (Table 1).

Table 1. Distribution of load levels for 5 raters across the 7 individual movements performed by 41 Subjects

			LOAD LEVEL		
Movement		# of Subjects	1	2	3
LE	Double Leg Squat	39/41	84	107	14
	Single Leg Squat	41/41	201	4	0
	Lunge	32/41	63	88	54
Trunk	Twist	39/41	119	73	13
	Bend	41/41	98	101	6
UE	Pull	33/41	54	60	91
	Push-up	34/41	60	76	69
Total Distribution			**679**	**509**	**247**
Percentage Total Distribution (%)			**47.32**	**35.47**	**17.21**

Overall, load levels assigned across the seven movements were either a load level 1 (47.32%) or a load level 2 (35.47%) (Table1). Raters assigned a load level 1 more often than a load level 2 or 3 when evaluating movements localized to the lower extremity or trunk. For each of the 7 movements tested, 205 load level assignments were available (5 raters multiplied by 41 subjects). The single leg squat demonstrated the highest level of rater agreement across all seven individually scored movements and raters assigned load level 1 to the majority of trials (201 /205) and agreed on 41 of 41 subjects for this task (Table 1, Figure 2d). In contrast, raters agreed on the load level assignments for fewer subjects and demonstrated a wider range of load level assignments for the pushup as well as the two tasks scored separately: the lunge and twist, and the bend and pull (Table 1) (Figure 2a; Figure 2b).

Figure 2. Load Level Distribution by 5 Raters across 41 Subjects



Six out of the seven movements of the MCS showed no observable trends across gender and load level. However, for the push-up in female subjects, a load level 1 was assigned to 41 of the 75 opportunities to rate the push-up task (15 female subjects multiplied by 5 raters) in contrast to the push-up task in male subjects, in which a load level of 3 was assigned to 63 out of 130 opportunities (26 male subjects multiplied by 5 raters) (Figure 2c).

Primary Impairments

Percent agreement for the presence of primary impairments varied across all seven movements (47-96%) (Table 2). The raters reached an 80% agreement threshold for only nine out of the 28 possible impairments across all seven movements. Shoulders were evaluated as a primary impairment in five out of the seven movements and demonstrated the least range in variability in agreement (61-95%) (Table 2). Depth of the movement was evaluated as a primary impairment in four out of the seven movements and demonstrated the greatest range in variability in agreement (47-96%) (Table 2). Lumbar spine and hips were evaluated in six out of the seven movements and revealed comparable ranges of percent agreement, 57-87% and 54-92%, respectively (Table 2). Of all seven individual movements, the single leg squat demonstrated the highest and most consistent percent agreement for three out of the four primary impairments (depth, lumbar spine, hips) (Table 2).

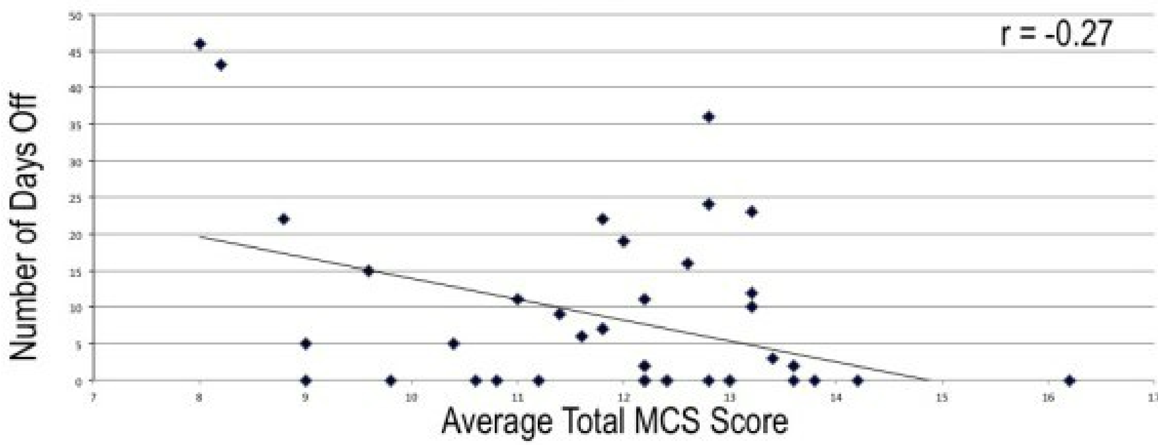
Table 2. Average percent agreement across 5 Raters on the presence of primary impairments for 41 subjects

	DOUBLE LEG SQUAT		LUNGE		TWIST		BEND		PULL		PUSH-UP		SINGLE LEG SQUAT	
Impairments	Shoulders	61%	Balance	85%	Shoulders	95%	Shoulders	81%	Shoulders	86%	Head	55%	Depth	96%
	Lumbar	79%	Lumbar	61%	Lumbar	68%	Lumbar	87%	Lumbar	57%	Shoulders	84%	Lumbar	80%
	Hips	67%	Hips	60%	Hips	79%	Hips	54%	Hips	92%	Lumbar	75%	Hips	83%
	Ankles/ Feet	57%	Ankles/ Feet	72%	Ankles/ Feet	62%	Depth	66%	Depth	47%	Depth	53%	Ankles/ Feet	53%

Injury Data

Subjects who sustained an injury did not score above an average total MCS score of 14 (range 8-14) out of 21 total points available. A very weak inverse correlation (r = -0.281, P = 0.206) existed between the average total MCS score and the total number of injuries sustained (n = 22). The majority of injuries in this cohort were lower extremity injuries and a weak inverse correlation existed between average total MCS score and number of lower extremity injuries (r = -0.381, P = 0.149). A moderate inverse correlation existed between average total MCS score and number of injuries sustained in the upper extremity (r = -0.408, P = 0.065). A very weak correlation existed between average total MCS score and number of injuries sustained in the head or trunk (r = -0.090, P = 0.691) as well as between average total MCS score and number of days off (r = -0.094, P = 0.676) (Figure 3). None of the correlations reached a statistically significant level.

Figure 3. Spearman's Correlation Coefficient between Average Total MCS Score and Total Number of Training Days Lost



Performance Data

There was a good correlation between average total MCS score and overall PRT score in both the fall (r = 0.447, P = 0.003) and spring (r = 0.540, P = 0.00) academic semesters, respectively. No significant correlation existed between the average total MCS scores of males subjects and (1) overall PRT score, (2) curl-up score, (3) push-up score or (4) 1.5-mile run time, in either the Fall nor the Spring academic semesters. In contrast, a strong positive correlation was found between the average total MCS scores of female subjects and overall PRT scores in the fall (r = 0.825, P = 0.00) and spring (r = 0.784, P = 0.007) semesters, respectively, such that females with lower MCS scores had a lower overall PRT scores. In addition, a strong positive correlation existed between the total average MCS score of female subjects and total push-up score (r = 0.884, P = 0.001) and a strong inverse correlation was found between total average MCS score and run time score in the fall semester (r = -0.768, P = 0.009). No significant correlation was established between average total MCS score and total curl-up score for the overall cohort for either male or female subjects.

DISCUSSION

The purpose of this study was to examine the reliability of the MCS and explore the associations between the MCS and injury incidence and physical performance in a group of

USNA Midshipmen. The results demonstrated that inter-rater reliability was good for total MCS score whereas intra-rater reliability for total MCS score ranged from moderate to good. In general, a weak inverse correlation existed between average total MCS score and injury incidence, and the initial MCS score correlated with PRT performance for female subjects, but not males.

Total MCS Score

Raters demonstrated good intra- and inter-rater reliability when assigning a total MCS score, a finding consistent with current MCS literature (Figure 1) (22). Similar screening tools such as the FMS, demonstrate variable inter-rater reliability (ICC = 0.38 – 0.99) when examined among raters with different training and experience (3, 19, 24-25, 27), including “novice” versus “expert” raters or those who underwent the standard training required to use the FMS (19). Butler et al. (3) determined higher inter-rater reliability between two “expert” certified raters; however, the study utilized newly revised and more specific scoring criteria during FMS administration making it difficult to discern the variable(s) responsible for increasing inter-rater reliability of the FMS. In this study, raters achieved high inter-rater reliability with only 40 contact hours of training on the MCS tool, suggesting that physical therapists, currently practicing in the military, could utilize the MCS as a cost-effective and efficient screen to reliably assess movement competency in military recruits (26).

The intra-rater reliability of the MCS was consistent with the reported intra-rater reliability of the FMS (ICC = 0.6-0.91) (24-25, 27). However, studies that have evaluated the intra-rater reliability of the FMS utilized varying time periods (48 hours to seven days) between re-evaluating the subjects’ performance (24-25, 27). As a result, a “learning effect” may have contributed to the achievement of high FMS intra-rater reliability. Our study required raters to allow four weeks to pass prior to observing digital recordings for the second time in order to eliminate potential bias. Despite the extended time period between ratings, raters demonstrated good intra-rater reliability in assigning a total MCS score. This finding further supports our assertion that individual raters can consistently categorize the movement competency of individual midshipman and do so over time.

Primary Impairments and Load Level

The MCS requires that the rater use specific criteria to identify the presence (or absence) of movement impairments during the performance of the seven movements to guide the rater to assign a particular load level. Current literature suggests that inter-rater reliability increases with the use of simplistic scoring criteria and decreases when the rater assesses and evaluates multiple joints that are moving simultaneously to complete a task (25). Thus, the analysis of percent agreement was based on the primary impairments only. Further analysis on additional secondary impairments was not conducted because these impairments carried minimal weight in load level assignment. Although the MCS uses simple scoring criteria, raters were required to evaluate multiple joints as they move simultaneously during one task, which likely contributed to the variation in agreement in the presence of primary impairments across raters (Table 2). Given the varied rater agreement when identifying the presence/absence of primary impairments, the MCS should not yet be used by clinicians to focus their therapeutic

interventions.
Despite variable agreement on the presence of primary impairments, raters demonstrated adequate agreement on load level scores, thus directly contributing to the high reliability observed in the total MCS score. Overall, load level scores were either load level 1 or 2 (Table 1) suggesting that the majority of the subjects could benefit from additional evaluation or supervision prior to initiating a standard training program. In general, raters reached higher agreement on load levels in movements that evaluated the lower extremity and trunk as compared to movements that evaluated the upper extremity (Table 1). Due to the high volume of lower extremity injuries sustained in the military, the high reliability observed across raters during movements evaluating the lower extremity and trunk may have clinical value (8, 10, 24, 28).

Individual Movement Tests
Double Leg Squat: The squat is a commonly utilized movement pattern in exercise prescription and daily movement (13, 23). Rater agreement varied widely for the presence of the four primary impairments listed for this task; however, raters reached highest agreement on the presence of impairment in the lumbar spine. The anatomical relationship between the lumbar spine and hips may explain some of the rater disagreement because the raters are required to discern which body segment is at fault (25) and they may have noted impairments in the hips, lumbar spine, or both. Despite rater disagreement on presence of primary impairments, raters were still able to reach acceptable agreement on load level for the squat.

Lunge and Twist: Adequate hip range of motion and proper muscle activation are required to stabilize the lumbar spine as the hip flexes during the forward lunge (13, 15) a mechanical relationship that makes it challenging for a clinician to identify which segment (if either) is impaired throughout the movement. As a result, high rater agreement was difficult to achieve when evaluating the lunge and twist (15). Similar to the squat, raters reached low agreement for the presence of impairments in hips and the lumbar spine during the lunge. However, during the twist, raters reached adequate agreement on load level likely due to having only one segment (i.e., trunk) to evaluate (25). Given that the lunge and twist are performed together, the rater was challenged to identify the correct portion of the task for which the movement impairment should be attributed, influencing overall reliability at the impairment level. Given disagreement on the presence of primary impairments, variation in load level assignment is inherent, reducing overall rater reliability for the lunge.

Bend and Pull: Bend movements and upper body pull patterns are commonly utilized measurements of movement competency given their high level of practical application during functional strength training (13, 14). The bend and pull, similar to the lunge and twist, is evaluated as two separate movements. It was anticipated there would be lower levels of agreement on body segments such as the shoulder because the shoulder region is a complex of the glenohumeral, acromioclavicular, sternoclavicular, and 'scapulothoracic' joints (25). Despite the biomechanical complexity of this region, raters achieved high agreement on the presence of primary impairments in the shoulders for the bend (81%) and pull (86%) similar to other studies where raters determined if movement dysfunction was present (9).

Push-Up: Raters demonstrated discrepancies in agreement when applying the criteria of 'head' and 'depth' for primary impairments when scoring the push-up. In this study, subjects lacking adequate upper body strength and stability often compensated for the inability to reach the appropriate 'depth' by flexing their cervical spine and head; thus, the subjects did not meet the scoring criteria for keeping the head centered throughout the push-up. Raters then decided whether the subject should be marked off for head, depth, or both. Given that 'head' and 'depth' are both primary impairments, variable agreement on the presence of either impairment resulted in lower agreement on load level scores for the push-up task.

Single Leg Squat: For this movement, the rater evaluated whether or not the depth of the subject's squat reached "thigh parallel to the ground" (13). A ceiling effect was created with this criterion because the majority of subjects could not achieve this position. Given that 'depth' is a primary impairment, the result is the automatic deduction of one load level, thus the majority of subjects immediately received a load level 2. Any additional primary impairment noted, whether one to three additional impairments, further reduced the subject's score for the single leg squat to a load level 1. Thus, a floor effect also existed for the single leg squat, and both the ceiling and floor effect contributed to high rater agreement in the single leg squat.

Gender and the MCS

The majority of female subjects scored a load level 1 on the push-up, whereas male subjects consistently scored higher. Due to increased shoulder joint mobility and decreased upper body strength, female subjects have difficulty stabilizing body segments when performing tasks such as the push-up (4, 22). A similar pattern was noted in the females subjects in the present study which likely contributed to lower load level distribution noted in female subjects (4). These findings are consistent with results reported by Reid et al. 2015 (22), in which the study identifies difficulty of adolescent female Netballers to demonstrate adequate upper body strength to optimally perform a push-up and obtain a load level 3.

Injury Incidence and the MCS

Given the recent literature that purports poor movement patterns are a strong potential risk factor for musculoskeletal injury development, it was predicted that a lower total MCS score would correlate with higher injury incidence overall (13) but demonstrated only a weak inverse relationship between initial average total MCS score and the number of (1) injuries and (2) number of days off from training duties. Bullock et al. reported that during military Basic Combat Training programs, 25% of male recruits and 50% of female recruits sustained one or more injuries related to training, of which 80% are overuse injuries in nature and occurred in the lower extremity (8, 10, 17, 20, 28). Current results support the concern regarding the large number of lower extremity overuse injuries in military populations as 17 out of the 22 total injuries sustained in this cohort during the first six months of training occurred in the lower extremity. Of subjects who sustained an injury, none received a score greater than 14 on the MCS, suggesting that these subjects has a greater movement dysfunction. Given that the cohort of subjects is in their first year at USNA, future research is needed to determine the predictive value of the MCS for this cohort over the next three years until graduation.

Physical Readiness Test Results

Physical fitness assessment batteries are common in all military branches prior to entrance into Basic Combat Training programs. USNA mandates participation by 4/C Midshipmen in an Initial Strength Test consisting of maximum number of curl-ups performed in two minutes, maximum number of push-ups performed in 2 minutes and a timed 1-mile run prior to the initiation of a summer conditioning program. Yet, for many, satisfying the demands of initial training places them at a higher risk for musculoskeletal injury development, especially without a screening and any remediation that is needed (18). In this small cohort, the female subjects who scored lower on the MCS also did poorly on their PRT during their first year at USNA. As this cohort is followed longitudinally, there can be an examination of subsequent PRT scores as well as musculoskeletal injury trends.

Limitations

Several limitations currently exist within this study. It is recognized that the MCS does not utilize a standardized protocol for the set-up of the video camera or positioning of the athlete in front of the digital recording. Therefore, at times raters may be challenged to adhere to the scoring criteria when there was inadequate capturing of the entire movement pattern or less than optimal camera angle with respect to the athlete. Standardized instruction to each athlete regarding movements was controlled through use a set of consistent verbal instruction and visual demonstration via PowerPoint. However, the raters were unable to provide instructions themselves as the video recording took place remotely at the USNA. Additionally, all participants were asked to remove all excessive or loose fitting clothing that might obscure the raters view. However, several declined to do so secondary to personal preference and therefore, clothing worn by participants may have prohibited raters from adequately viewing critical body segments such as the lumbar spine in order to make a judgment regarding its position during movements. Lastly, there was one scoring criteria further defined by raters (wide hands allowed for the “standard push-up”) and this altered the standardized scoring criteria but increased rater consistency during the evaluation of the push-up. The specific scoring criteria for each movement are currently under examination to increase clarity, which will likely contribute to increases reliability of the MCS in future use.

More significantly, the authors acknowledge the small sample size of the current cohort, limiting the generalizability of the study to larger military populations. The current cohort represents a convenience sampling of students willing to participate in a comprehensive study during their first year at a military service academy. Additionally, said participants have mandatory participation in either intramural, club sports, or varsity athletics which may contribute to further development of overuse injuries. Finally, it is possible that some of the participants did not report or have documentation of certain previous injuries prior to participation in the study that, if reported, could have influenced/better explained their respective MCS rating.

CONCLUSION

The MCS offers a potential solution to the U.S. Armed Forces current need for a reliable and easy to use screening tool. Raters were able to identify individuals within the USNA population needing further evaluation prior to the initiation of training programs as evidenced by the correlation between the MCS score and PRT data for females. Future research will focus on examining the relationship between total MCS score and injury risk in USNA cohort in order to determine the predictive value of the MCS. The implementation of the MCS into military screening protocols prior to training may offer a pre-emptive solution to the burden of overuse injuries on military capacity.

ACKNOWLEDGMENTS: The authors would like to acknowledge the collaboration from the United States Naval Academy and USNA MIDN Ted Johnson for his assistance with data collection. We would also like to thank Sonya Worth, PT, OCS, PGDipHSc for her time in sharing her experience with and knowledge of the MCS tool and Alan B. Howard, for his assistance with our data analysis. Lastly, we would like to acknowledge the contributions of Ryan Lunny, SPT, Alexandra Epstein, SPT, and Rachel Wellman, SPT for their assistance in data reduction and collation and their effort in helping to make this project successful.

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Athlete **Sport** **Date** **MCS Score**

SCREENING INSTRUCTIONS: Based on the MCS criteria mark the PRIMARY or SECONDARY area that is of concern when observing the athlete perform the MCS movement patterns.

PATTERN	PRIMARY	SECONDARY	LOAD LEVEL	COMMENTS
SQUAT	o SHOULDERS o LUMBAR o HIPS o ANKLES/FEET	o HEAD o KNEES o DEPTH o BALANCE	1 2 3	
LUNGE & TWIST (The Lunge)	o BALANCE o LUMBAR o HIPS o ANKLES/FEET	o HEAD o KNEES o DEPTH	1 2 3	
LUNGE & TWIST (The Twist)	o SHOULDERS o LUMBAR o HIPS o ANKLES/FEET	o HEAD o KNEES o DEPTH o BALANCE	1 2 3	
BEND & PULL (The Bend)	o SHOULDERS o LUMBAR o HIPS o DEPTH	o HEAD o KNEES o ANKLES/FEET o BALANCE	1 2 3	
BEND & PULL (The Pull)	o SHOULDERS o LUMBAR o HIPS o DEPTH	o HEAD o KNEES o ANKLES/FEET o BALANCE	1 2 3	
PUSH UP	o HEAD o SHOULDERS o LUMBAR o DEPTH	o HIPS o KNEES o ANKLES / FEET o BALANCE	1 2 3	
SINGLE LEG SQUAT	o DEPTH o LUMBAR o HIPS o ANKLES / FEET	o HEAD o SHOULDERS o KNEES o BALANCE	1 2 3	

SCORING INSTRUCTIONS		
Load Level	PRIMARY SECONDARY	Considerations
1	2+ and / or 4	The numbers in the PRIMARY and SECONDARY columns depict the number of areas that were marked during the screen. Select the 1, 2 or 3 in the Load Level column after adding up the checked areas for each pattern.
2	1 and /or 0-3	
3	0 and /or 0-2	
SCORING		
GOOD 17 - 21	MODERATE 11 - 16	POOR 7 - 10