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Movement Clearing Screens for Military Service Member Musculoskeletal Injury Risk Identification

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Context: Pain during movement screens is a risk factor for musculoskeletal injury (MSKI). Movement screens often require specialized or clinical expertise and large amounts of time to administer.

Objective: Evaluate if self-reported pain (1) with movement clearing screens is a risk factor for any MSKI, (2) with movement clearing screens is a risk factor for body region–specific MSKIs, and (3) with a greater number of movement clearing screens progressively increases MSKI risk.

Design: Retrospective cohort study.

Setting: Field-based.

Patients or Other Participants: Military service members ($n = 4222$).

Main Outcome Measure(s): Active-duty service members self-reported pain during movement clearing screens (Shoulder Clearing, Spinal Extension, Squat-Jump-Land). Musculoskeletal injury data were abstracted up to 180 days post-screening. A traffic light model grouped service members if they self-reported pain during 0 (Green), 1 (Amber), 2 (Red), or 3 (Black) movement clearing screens. Cox proportional hazards models adjusted for age, gender, body mass index, and prior MSKI determined the relationships between pain during movement clearing screens with any and body region–specific MSKIs.

Results: Service members self-reporting pain during the Shoulder Clearing (adjusted hazard ratio and 95% confidence interval [HR_{adj} (95% CI)] = 1.58 [1.37, 1.82]), Spinal Extension (HR_{adj} = 1.48 [1.28, 1.87]), or Squat-Jump-Land (HR_{adj} = 2.04 [1.79, 2.32]) tests were more likely to experience any MSKI than service members reporting no pain. Service members with pain during the Shoulder Clearing (HR_{adj} = 3.28 [2.57, 4.19]), Spinal Extension (HR_{adj} = 2.80 [2.26, 3.49]), or Squat-Jump-Land (HR_{adj} = 2.07 [1.76, 2.43]) tests were more likely to experience an upper extremity, spine, back, and torso, or lower extremity MSKI, respectively, than service members reporting no pain. The Amber (HR_{adj} = 1.69 [1.48, 1.93]), Red (HR_{adj} = 2.07 [1.73, 2.48]), and Black (HR_{adj} = 2.31 [1.81, 2.95]) cohorts were more likely to experience an MSKI than the Green cohort.

Conclusions: Self-report movement clearing screens in combination with a traffic light model provide clinician- and nonclinician-friendly expedient means to identify service members at MSKI risk.

Key Words: pain, injury prediction, clinical tools

Key Points

- Military service members reporting pain on any movement clearing screen are at greater risk for any musculoskeletal injury than service members reporting no pain.
- Musculoskeletal injury risk progressively increases as military service members report pain on more movement clearing screens compared with service members reporting no pain.
- Self-report movement clearing screens in combination with a traffic light model provide an expedient means to identify military service members at greater musculoskeletal injury risk, which may be executed at scale without medical providers.

Noncombat-related musculoskeletal injuries (MSKIs) significantly diminish individual military service member and force medical readiness.[1,2] In 2019, MSKIs accounted for 55% of all limited duty days (ie, 10 million days), precluding 4% of active-duty Army service members from deploying with their units.[1,2] Musculoskeletal injuries also incur significant financial and medical resource burdens for the military.[3] Thus, identifying service members at the greatest risk for MSKI is essential so they may be targeted with MSKI risk mitigation interventions in a proactive manner.

Multifactorial MSKI risk assessments are necessary to comprehensively identify key variables contributing to MSKI risk.[4,5] A common component of comprehensive MSKI risk assessments is movement screens (eg, squats, jumps).[6–8] A variety of movement screens have been implemented, with varying levels of success in identifying individuals with greater MSKI risk in both military and civilian populations.[9,10] Most of these screens can require a significant amount of time and technical expertise to employ. These requirements make movement screens impractical for most clinicians and non-clinicians when assessing service members, athletes, or patients en masse, given time constraints and limited clinical personnel or resources. Clinical-based movement screens, including the Landing Error Scoring System and Functional Movement Screen (FMS), reduce the need for technical expertise (eg, computer software expertise) but still require extensive time and training to administer.[8] Optimizing the efficiency of clinical-based movement screens will aid clinicians' and non-clinicians' time constraints in identifying MSKI risks.

As a whole, the FMS does not have clinical utility in predicting future MSKI among active-duty service members.[10] However, movement clearing screens, which identify pain during prescribed movements, have shown clinical utility for identifying service members at greater MSKI risk.[11–13] Additionally, movement clearing screens require minimal time and no equipment or technical expertise, as they are entirely self-reported.[11–13] US Army Rangers and conventional Army soldiers self-reporting pain during movement clearing screens were more likely to sustain an MSKI than individuals who did not report pain.[12,13] Authors of a study among active-duty soldiers found that reporting pain on the deep squat, hurdle step, in-line lunge, trunk stability push-up, or rotary stability of the FMS movements related to future MSKI; however, they only investigated pain during the FMS movements in isolation and not in combination with each other to assess future MSKI risk.[14] Authors of only 1 study have examined if pain during multiple movement assessments versus only 1 movement assessment increases future MSKI risk.[11] Army soldiers reporting pain on 1, 2, 3, or 4 or more of the 7 FMS movements exhibited a 40%, 86%, 142%, or 183% higher risk of future MSKI, respectively, than those reporting no pain.[11] Further, specific relationships between movement clearing screens and body region–specific MSKIs (ie, Shoulder Clearing Test and upper extremity MSKI) have not been explored. Collectively, these findings suggest self-report movement clearing screens may be able to identify MSKI risk with similar accuracy and greater efficiency compared with more complex clinician-assessed movement screens.[11]

The primary purpose of this study was to determine if self-reported pain during any movement clearing screen (Shoulder Clearing Test, Spinal Extension Test, Squat-Jump-Land) was associated with a greater risk for future MSKI within 180 days of testing. Secondarily, we assessed if pain during each movement clearing screen was associated with a greater risk for a relevant body region–specific MSKI (eg, Shoulder Clearing Test pain and upper extremity MSKI). Finally, we determined if reporting pain on multiple movement clearing screens progressively increased service members' MSKI risk compared with reporting no pain on any movement clearing screen. We hypothesized reporting pain on any movement clearing screen would be a risk factor for future MSKI within 180 days of testing. Secondarily, we hypothesized pain during a specific movement clearing screen would be a risk factor for future body region–specific MSKIs. Finally, we hypothesized that MSKI risk would progressively increase as service members reported pain on additional movement clearing screens.

METHODS

We performed a retrospective cohort study[15] of existing data, including a self-report musculoskeletal movement clearing screen and MSKI data captured via International Classification of Disease-10 (ICD) codes in the Military Health System Management Analysis and Reporting Tool (MHS MART [M2]). The M2 is a data repository, built from medical encounter data, that allows researchers to query MSKI data (among other pathologies) for clinic operations and research purposes.[16] The protocol was exempt from institutional review board review, as it involved secondary research for which consent was not required.

Participants

We included active-duty service members (n = 4222) in-processing to a single military unit located at Fort Liberty, NC, between December 10, 2020, and March 1, 2022. All service members in-processing to the unit completed 3 self-report musculoskeletal movement clearing screens as part of their unit-directed in-processing.[17] Service members who completed all 3 movement clearing screens were included in our study. There were no additional inclusion or exclusion criteria.

Self-Report Movement Clearing Screens and Demographics

All movement screens were completed en masse during the military unit's standard in-processing, and most service members wore their Operational Camouflage Pattern uniform boots. A non-medical military unit representative delivered a standardized script on how to complete the assessments. After the service members completed each movement screen, they recorded whether they felt pain on that screen (ie, self-reported). No operational definition of pain was provided to the service members (ie, they interpreted pain via their own personal definitions).

The movement clearing screens consisted of the Shoulder Clearing Test, Spinal Extension Test, and Squat-Jump-Land. The military unit selected the movement screens based on the available literature and to mimic the functional tasks of an airborne unit.[11–13] The Shoulder Clearing and Spinal Extension Tests were sourced from the FMS. The military unit adapted the FMS deep squat to the Squat-Jump-Land to mimic the functional tasks of an airborne unit.

The Shoulder Clearing Test required service members to place their palm from one hand on the opposite shoulder (eg, left palm on right shoulder) and elevate their elbow as high as possible; this was completed bilaterally (Figure 1A).[7] The Spinal Extension Test required service members to assume a push-up position (prone on the ground) and lift their chest off the ground until their elbows were straight or extended while attempting to keep their pelvis flat in contact with the ground (Figure 1B). The Squat-Jump-Land consisted of service members assuming a squat position, performing a maximum vertical jump with no countermovement, and then landing (Figure 1C). Additionally, at the time of the movement clearing screens, service members self-reported their height, weight, and if they experienced an MSKI in the year before the screening that resulted in medical care or persisted longer than a week.[17]

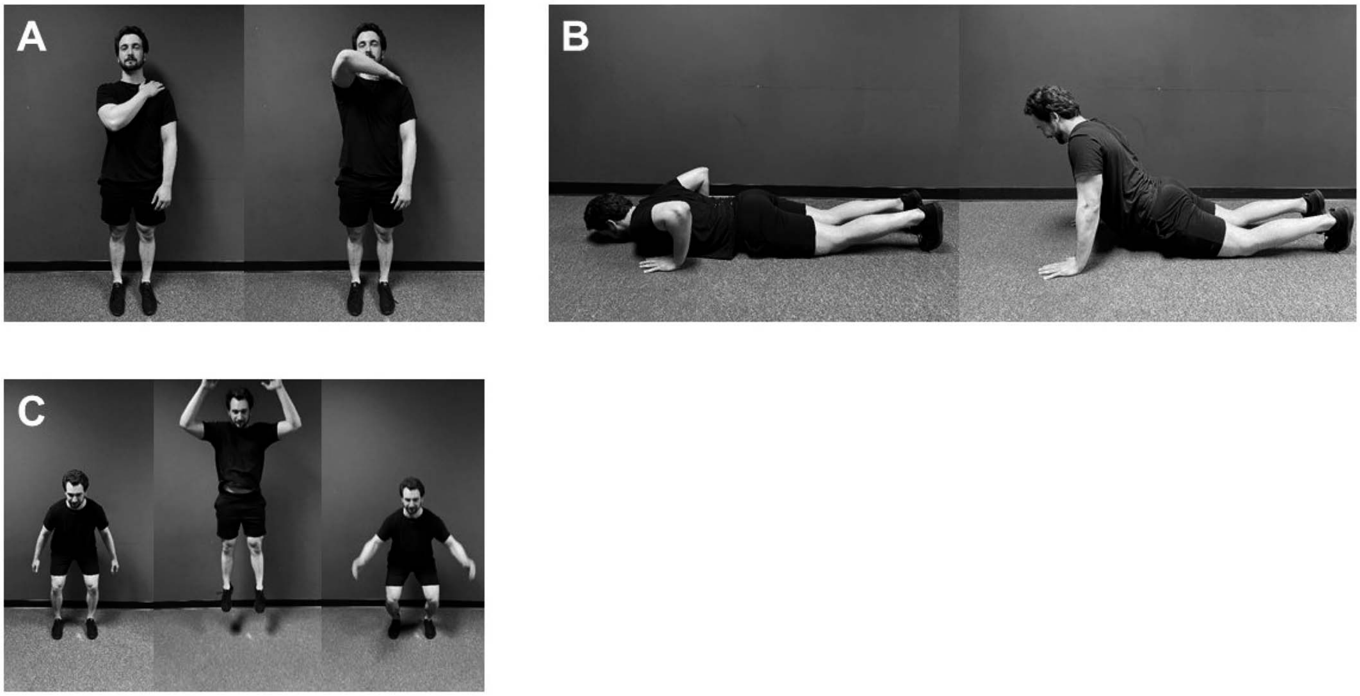

Figure 1. A, Shoulder Clearing Test. B, Spinal Extension Test. C, Squat-Jump-Land.

Musculoskeletal Injury Data

Military Health System electronic medical record data are captured and cataloged in the M2 with ICD-10 codes. Based on a prior taxonomy, we retrospectively pulled ICD-10 codes associated with MSKI encounters from the Comprehensive Ambulatory Provider Encounter Records in the M2.[18,19] The codes were pulled to identify service members who sustained MSKIs within 180 days of completing the movement clearing screens. Each MSKI was classified by body region: head and neck, upper extremity, spine and back, torso, lower extremity, and other. Our primary analyses focused on MSKIs across all body regions. Our secondary analyses focused only on body region–specific MSKIs relevant to the movement clearing screen of interest. We also abstracted age and gender data from the M2.

Data Reduction

Movement clearing screen results were recorded as *yes* (pain during movement) or *no* (no pain during movement) for each movement clearing screen. Service members were dichotomized as self-reporting having pain on each individual movement clearing screen of interest versus no pain on the movement clearing screen of interest. The Shoulder Clearing Test was completed bilaterally but reported as a single outcome (ie, regardless of unilateral or bilateral pain, the outcome was recorded as *yes* in our data). Body mass index was calculated from self-reported height and weight.

Service members were classified as *injured* if 1 or more MSKI ICD-10 codes were identified in the M2 regardless of the number of different ICD-10 codes or the number of times the same code appeared in the medical record. Service members for whom an MSKI ICD-10 was not identified within the medical record during the 180-day follow-up period were considered *uninjured*. The first MSKI experienced during our surveillance period was used in our analyses, regardless of the body region, for the any body region analysis and traffic light model analysis. To examine movement clearing screen pain and body region–specific MSKI risk, we categorized participants as injured based on the time to their first MSKI to the body region of interest, not necessarily their first MSKI overall during the surveillance period. For example, if a service member experienced a shoulder joint injury as their second overall MSKI during the surveillance period, then the shoulder joint injury was used for the Shoulder Clearing Test body region–specific MSKI analysis. The Shoulder Clearing Test identified upper extremity MSKI risk (shoulder joint and distal through the fingers); the Spinal Extension Test identified spine, back, and torso MSKI risk; and the Squat-Jump-Land identified lower extremity MSKI risk (hip joint and distal through the toes). Musculoskeletal injuries included in the head and neck and other categories were not included in the body region–specific analyses.

To determine if reporting pain on multiple movement clearing screens progressively increased the risk for any MSKI, we developed a traffic light model that combined all 3 movement clearing screens into a single outcome. Service members were categorized as Green (no pain on any movement clearing screen), Amber (pain on 1 movement clearing screen), Red (pain on 2 movement clearing screens), or Black (pain on 3 movement clearing screens). The first MSKI experienced during our surveillance period was used in our analyses regardless of the affected body region.

Data Analysis

Descriptive statistics were calculated as means and standard deviations, percentages, and medians as appropriate. We evaluated each movement screen separately, such that we did not account for pain experienced during the other

Table 1. Service Member Demographics (Mean ± SD or No. [%])[a]

	All Service members (n = 4222)	Uninjured (n = 2716)	Injured (n = 1506)
Age, (y)	24.3 ± 5.6	23.8 ± 5.2	25.1 ± 6.3
Body mass index, kg/m^2	25.6 ± 3.1	25.3 ± 3.1	25.6 ± 3.2
Gender, No. (% female)	517 (12.2)	253 (9.3)	264 (17.5)
Prior MSKI history, No. (% yes)	671 (15.9)	259 (9.5)	412 (27.4)
Pain on movement clearing screen, No. (% yes)	985 (23.3)	442 (16.3)	543 (36.1)
Pain on Shoulder Clearing Test, No. (% yes)	473 (11.2)	206 (7.6)	267 (17.7)
Pain on Spinal Extension Test, No. (% yes)	414 (9.8)	193 (7.1)	221 (14.7)
Pain on Squat-Jump-Land, No. (% yes)	571 (13.5)	215 (7.9)	356 (23.6)

Abbreviation: MSKI, musculoskeletal injury.

[a] All (age, body mass index, gender, prior injury history, pain on movement clearing screen, pain on Shoulder Clearing Test, pain on Spinal Extension Test, pain on Squat-Jump-Land) comparisons between injured and uninjured service members were statistically significant ($P < .05$).

movement screens, except for our third objective (traffic light model), in which we examined the effect of pain with multiple movement screens on MSKI risk. To determine if self-reported pain during an individual movement clearing screen was associated with any MSKI, we used unadjusted and adjusted Cox proportional hazards models. Cox proportional hazards were adjusted by age, gender (male or female), body mass index, and prior MSKI history (yes or no). These covariates were chosen as they relate to MSKI risk and pain.[17,20] Similar analyses, including the same covariates, estimated the association between self-reported pain on the individual movement clearing screens and relevant body region–specific MSKI risk. Further, similar analyses again were used to determine if the traffic light model, based on the quantity of pain across all movement clearing screens, could differentiate service members at risk of sustaining any MSKI. We only compared the traffic light model Amber, Red, and Black cohorts to the Green cohort, as our reference group. Unadjusted and adjusted hazard ratios (HR_{adj}) and 95% CIs were calculated for each Cox proportional hazards model. Our measure of discriminatory ability for the traffic light model was the *C-Index* (ie, C-Statistic, concordance statistic), which can be defined as a model's ability to correctly classify participants into specific groups based on their risk scores (ie, pain on movement screenings in our model).[21] The C-Index is like the area under the curve and is interpreted as weakly generalizable (0.50–0.70), moderately generalizable (0.70—0.85), and strongly generalizable (0.85–1.00).[22,23] The C-Index was used to determine the ability of our model to discriminate between service members who do and do not experience a future MSKI based on the number of movement screenings for which they report pain. Additionally, for the traffic light model, the measure of calibration, or accuracy, was the Integrated Brier Score. The Brier Score is the mean square difference between the true classes and the predicted probabilities.[24] The Integrated Brier Score is the average for all the Brier Score values over a specified time interval.[25] The score interpretation ranges from 0.00 (*perfect accuracy*) to 1.00 (*perfect inaccuracy*).[26,27] For all models, multicollinearity was evaluated with variance inflation factor (VIF) calculations; any variable with a VIF > 5 was removed from the model. All analyses were conducted using R Studio version 4.4.2. Survival analysis packages included tidyverse, survival, and survminer, and significance for all models was set a priori $\alpha \leq .05$.

RESULTS

Demographics

Service members who went on to experience an MSKI (injured) and those who did not experience an MSKI (uninjured) differed in age, body mass index, gender, prior MSKI history, and pain during the movement clearing screens (Table 1). Similarly, the Amber, Red, and Black cohorts differed from the Green cohort in age, body mass index, gender, prior MSKI history, and pain during the movement clearing screens, except for the proportion of females between the Green and Black cohorts (Table 2). The Amber, Red, and Black cohorts were not compared, as our survival analyses were in reference to the Green cohort.

Pain During Movement Clearing Screens and Any Musculoskeletal Injury

Service members who self-reported pain on the Shoulder Clearing Test ($HR_{adj} = 2.11$), Spinal Extension Test ($HR_{adj} = 1.95$), or Squat-Jump-Land ($HR_{adj} = 2.84$) were more likely ($P < .001$ for all) to experience any MSKI within 180 days of in-processing than service members who did not report pain (Table 3). For all variables across all 3 models, the VIF ranged from 1.03 to 1.20; therefore, multicollinearity was considered not to be present.

Pain During Movement Clearing Screens and Body Region–Specific Musculoskeletal Injury

Service members who self-reported pain on the Shoulder Clearing Test were more likely ($HR_{adj} = 3.28$, $P < .001$) to experience an upper extremity MSKI than service members who did not report pain on the Shoulder Clearing Test (Table 3). Service members who reported pain on the Spinal Extension Test were more likely ($HR_{adj} = 2.80$, $P < .001$) to experience a spine, back, or torso MSKI than service members who did not report pain on the Spinal Extension Test (Table 3). Service members who reported pain on the Squat-Jump-Land were more likely ($HR_{adj} = 2.07$, $P < .001$) to experience a lower extremity MSKI than service members who did not report pain on the Squat-Jump-Land (Table 3). For all variables across all 3 models, the VIF

Table 2. Traffic Light Model Demographics (Mean ± SD or No. [%])[a]

	Green Cohort (n = 3237)[b]	Amber Cohort (n = 630)[c]	Red Cohort (n = 237)[d]	Black Cohort (n = 118)[e]
Age, y	23.6 ± 5.1	25.6 ± 6.0	27.2 ± 7.0	30.6 ± 7.7
Body mass index, kg/m^2	25.3 ± 3.1	26.1 ± 3.1	26.2 ± 3.0	26.9 ± 3.3
Gender, No. (% female)	355 (11.0)	108 (17.1)	40 (16.9)	14 (11.9)
Prior MSKI history, No. (% yes)	302 (9.3)	216 (34.3)	96 (40.5)	57 (48.3)
Pain on movement clearing screen, No. (% yes)	0 (0.0)	630 (100.0)	237 (100.0)	118 (100.0)
Pain on Shoulder Clearing Test, No. (% yes)	0 (0.0)	214 (34.0)	141 (59.5)	118 (100.0)
Pain on Spinal Extension Test, No. (% yes)	0 (0.0)	137 (21.7)	159 (67.1)	118 (100.0)
Pain on Squat-Jump-Land, No. (% yes)	0 (0.0)	279 (44.3)	174 (73.4)	118 (100.0)
MSKI during surveillance period, No. (% MSKI)[f]	963 (29.7)	319 (50.6)	148 (62.4)	76 (64.4)

Abbreviation: MSKI, musculoskeletal injury.

[a] All means and proportions were significantly different ($P < .05$) between the Green and the Amber, Red, and Black cohorts, except for the proportion of females between the Green and Black cohorts ($P = .999$). The Amber, Red, and Black cohorts were not compared, as our survival analyses were in reference to the Green cohort.

[b] Green cohort: No pain on movement clearing screens.

[c] Amber cohort: Reported pain on 1 movement clearing screen.

[d] Red cohort: Reported pain on 2 movement clearing screens.

[e] Black cohort: Reported pain on 3 movement clearing screens.

[f] MSKI during the surveillance period is reported as the No. (%) of service members who experienced an MSKI within 180 days after their in-processing between December 10, 2020, and March 1, 2022.

ranged from 1.04 to 1.23; therefore, multicollinearity was considered not to be present.

Traffic Light Model

The Amber ($HR_{adj} = 1.69$), Red ($HR_{adj} = 2.07$), and Black ($HR_{adj} = 2.31$) cohorts were more likely ($P < .001$ for all) to experience any MSKI than the Green cohort (Table 4). Median survival probability was the longest for service members categorized as Green (>180.0 days); the median survival probabilities for the Amber, Red, and Black cohorts were 174.5, 111.0, and 79.0 days, respectively (Figure 2). The unadjusted and adjusted (ie, when covarying for age, gender, body mass index, and prior MSKI history) C-Indices were 0.59 and 0.63, respectively, indicating the traffic light model had poor discriminatory ability. However, the unadjusted and adjusted Integrated Brier Scores were 0.147 and 0.145, respectively, indicating a moderate level of accuracy. The VIF for all variables ranged from 1.03 to 1.22; therefore, multicollinearity was considered not to be present.

DISCUSSION

Service members who self-reported pain on any movement clearing screen were at a greater risk for any MSKI within 180 days of testing and body region–specific MSKIs than service members who did not self-report pain. Additionally, our traffic light model is an expedient method that can be used by clinicians and non-clinicians (eg, sport coaches) for identifying service members at greater MSKI risk, as service members categorized as Amber, Red, or Black were 1.7 to 2.3 times more likely to sustain an MSKI than those reporting no pain (Green cohort). However, the discriminatory ability of the traffic light model was poor (C-Index = 0.63). Our results agree with prior literature in

Table 3. Adjusted and Unadjusted Hazard Ratios With 95% Confidence Intervals for Self-Reported Pain During Movement Clearing Screens and Musculoskeletal Injury[a]

	Any Musculoskeletal Injury		Body Region–Specific Musculoskeletal Injury[b]	
	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio (95% CI)	Unadjusted Hazard Ratio (95% CI)	Adjusted Hazard Ratio (95% CI)
Pain on Shoulder Clearing Test				
No	Reference	Reference	Reference	Reference
Yes	2.11 (1.85, 2.41)	1.58 (1.37, 1.82)	3.95 (3.14, 4.96)	3.28 (2.57, 4.19)
Pain on Spinal Extension Test				
No	Reference	Reference	Reference	Reference
Yes	1.95 (1.69, 2.25)	1.48 (1.28, 1.87)	3.40 (2.80, 4.13)	2.80 (2.26, 3.49)
Pain on Squat-Jump-Land				
No	Reference	Reference	Reference	Reference
Yes	2.84 (2.52, 3.20)	2.04 (1.79, 2.32)	2.88 (2.50, 3.34)	2.07 (1.76, 2.43)

[a] P values for all adjusted and unadjusted models were <.001. For all service members, 11.2%, 9.8%, and 13.5% reported pain on the Shoulder Clearing Test, Spinal Extension Test, and Squat-Jump-Land, respectively.

[b] For body region–specific musculoskeletal injury, the Shoulder Clearing Test identified upper extremity MSKI risk (shoulder joint and distal through the fingers), the Spinal Extension Test identified spine and back and torso MSKI risk, and the Squat-Jump-Land identified lower extremity MSKI risk (hip joint and distal through the toes).

Table 4. Adjusted and Unadjusted Hazard Ratios With 95% Confidence Intervals for the Traffic Light Model[a]

	Unadjusted Hazard Ratio[b]	95% CI	P Value	Adjusted Hazard Ratio[c]	95% CI	P Value
Traffic light						
Green	Reference	NA	NA	Reference	NA	NA
Amber	2.12	1.87, 2.41	<.001	1.69	1.48, 1.93	<.001
Red	2.86	2.40, 3.40	<.001	2.07	1.73, 2.48	<.001
Black	3.34	2.64, 4.22	<.001	2.31	1.81, 2.95	<.001
Age	1.04	1.03, 1.04	<.001	1.01	1.00, 1.02	.046
Gender						
Female	Reference	NA	NA	Reference	NA	NA
Male	0.56	0.49, 0.64	<.001	0.58	0.51, 0.66	<.001
Body mass index	1.05	1.03, 1.07	<.001	1.03	1.01, 1.05	<.001
Prior MSKI history						
No	Reference	NA	NA	Reference	NA	NA
Yes	2.78	2.49, 3.12	<.001	2.08	1.84, 2.35	<.001

Abbreviations: MSKI, musculoskeletal injury; NA, not applicable.

[a] All factors were significant at the $P < .001$, except for the adjusted hazard ratio age, which was significant at the $P = .046$.

[b] The unadjusted hazard ratios are the univariate relationship between the variable of interest and future MSKI. For example, age alone had an unadjusted hazard ratio of 1.04 in relation to future MSKI.

[c] The adjusted hazard ratios are shown for the multivariable model containing the traffic light (ie, pain on movement clearing screens), age, gender, body mass index, and prior MSKI history. For example, age, after controlling for traffic light, gender, body mass index, and prior MSKI history, had a hazard ratio of 1.01 in relation to future MSKI.

which authors investigated pain during functional movements and MSKI risk, while adding to the existing literature on MSKI risk by body region and the traffic light model.[11–13]

Pain During Movement Clearing Screens and Any Musculoskeletal Injury

Our findings agree with prior researchers that found service members who reported pain during any FMS movement (eg, in-line lunge, deep squat), not just clearing screens, have a greater risk for future MSKI.[11–13] However, what is unique about our work is we only examined 3 movement clearing screens, which require limited time and no clinical or technical expertise, whereas authors of other studies included both functional movement assessments and movement clearing screens (ie, 7 total movements).[11–13] Reducing the number of movement clearing screens will better enable health care providers and non–health care providers (eg, strength and conditioning coaches) to conduct MSKI risk evaluations en masse and thus improve the feasibility of MSKI risk assessments. This is primarily because all MSKI risks assessed in this study were entirely self-reported. More widespread MSKI risk assessments will result in the identification of more service members with higher MSKI risk, for whom MSKI risk mitigation interventions can be developed and implemented, resulting in fewer MSKIs.

Pain During Movement Clearing Screens and Body Region–Specific Musculoskeletal Injury

Self-reported pain during a specific movement clearing screen is a risk factor for relevant body region–specific MSKIs. Pain may increase the risk for MSKI for a variety of reasons. First, pain may cause an individual to alter their movement patterns.[28] This may result in aberrant joint and muscle loading to avoid undue strain and damage to the bone or soft tissue, both acutely (ie, service members landing from a jump may favor and overload the contralateral leg) and chronically (ie, service members adopt movement patterns that abnormally load tissues), increasing MSKI risk.[29] Second, pain causes changes in strength and the rate of force development.[30,31] Thus, service members with pain during movement may have reduced capacity to produce muscle forces sufficient to attenuate rapid loading of bones and soft tissues that may increase MSKI risk.[32] Additionally, the relationship between pain and care-seeking behavior within military contexts is complex. It is also possible service members who self-report pain may be more likely to seek care for their MSKI or are already undergoing treatment and therefore have a greater number of medical encounters and more opportunities to disclose their MSKIs.[33,34] With the new knowledge generated from our study, future researchers should investigate if reducing pain during movement decreases MSKI risks.

Traffic Light Model

Our most clinically important finding is our traffic light model can be used as a screening tool to efficiently identify service members at greater risk of sustaining an MSKI. Once these service members are identified, more in-depth assessments can be used to identify more specific MSKI risk factors and create appropriate, individualized MSKI risk reduction programs. We observed that, as service members reported pain on more movement clearing screens, MSKI risk increased.

It should be noted our traffic light model displayed poor discriminatory ability; this slightly limits its clinical utility. However, our traffic light model results are like prior research, in which authors found reporting pain on multiple FMS tests progressively increased MSKI risk among US Army service members.[11] The benefit of our traffic light model is it only included 3 movement clearing screens,

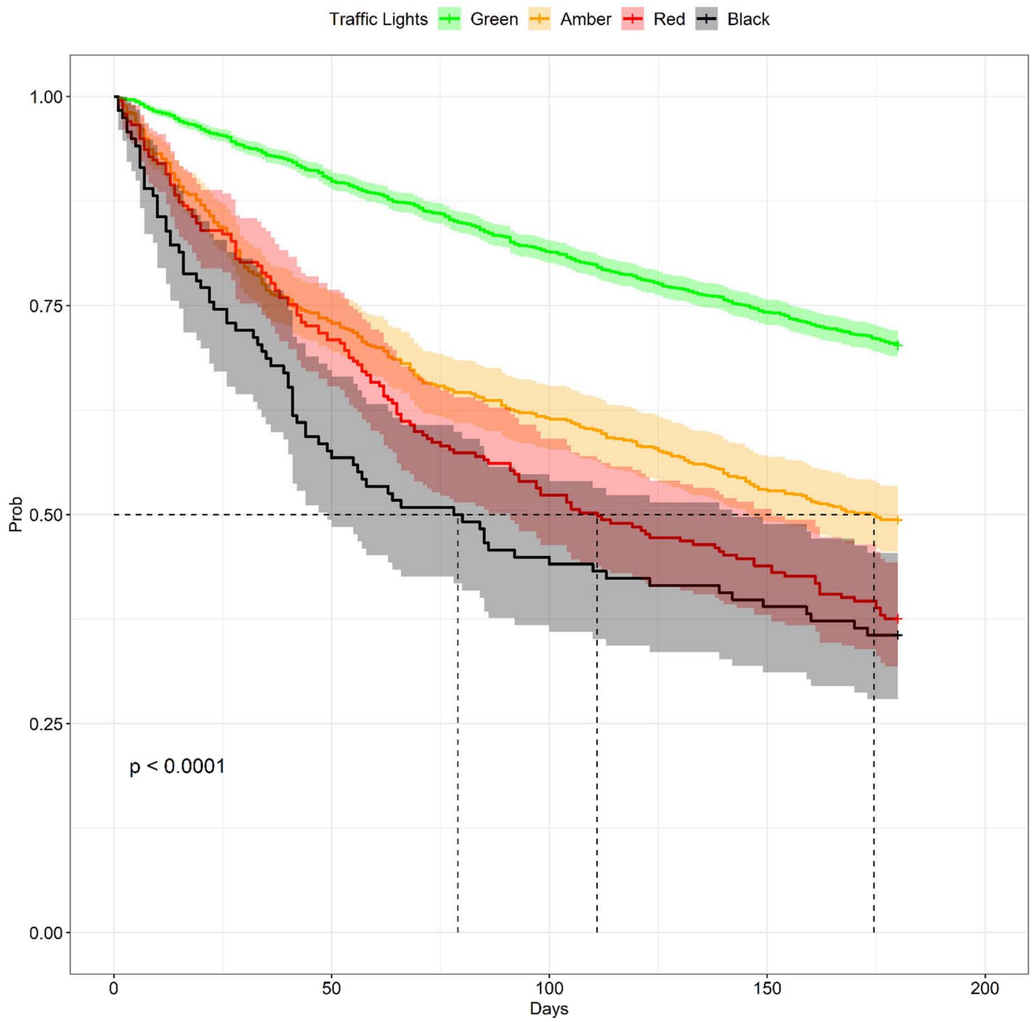

Figure 2. Traffic light model Kaplan-Meier curves. Green is the reference group. Dashed lines represent median survival probability. The median survival probabilities for the Amber, Red, and Black cohorts were 174.5, 111.0, and 79.0 days, respectively.

while authors of previous studies used the entire FMS battery (7 total tests); further, our traffic light model was highly accurate (Integrated Brier Score = 0.145).[11] This makes our model more efficient while still achieving similar results to prior research. Additionally, MSKI risk is influenced by multiple factors (eg, biomechanics, prior MSKI, psychological factors), and our model only had 1 risk factor (pain) while controlling for other risk factors.[32,35–37] This again highlights the traffic light model's efficiency. Lastly, our traffic light model was entirely self-report, meaning it can be administered by anyone, regardless of their clinical expertise or lack thereof. Thus, while the traffic light model is not without its limitations, it may still have clinical utility as an initial tool to help triage service members into high versus low MSKI risk cohorts. The high-risk cohort can then undergo additional assessments, as necessary.

For greater context on the traffic light model's efficiency, the military unit was able to assess up to 150 service members in as little as 30 minutes using a larger test battery that included the movement screens reported here and 16 self-report items (demographics, general health, and physical fitness).[17] Given our traffic light model only included the movement screens, it is more efficient than the comprehensive MSKI risk assessment conducted by the unit and more efficient than conducting the FMS battery used in previous research.[11]

Furthermore, our movement clearing screens do not require any specialized equipment or clinical expertise to administer. Therefore, our traffic light model can serve as an easy-to-implement decision support tool for health care and non–health care providers alike. For example, 86.9% of surveyed athletic trainers strongly agreed that clinical prediction rules and diagnostic algorithms would benefit the profession.[38] Multiple medical specialties are involved in the well-being (prevention and treatment of MSKIs) of service members, and clinical prediction rules would likely benefit them all.[39] Thus, the traffic light model may aid clinicians in identifying service members who should undergo additional MSKI risk evaluations. As observed in our study, the Black cohort had the highest risk for future MSKI, and the number of service members within this cohort is small enough (2.8% of our sample population) to connect with health care providers, appropriate resources, or both that can conduct comprehensive musculoskeletal assessments and provide individualized programs for these high-risk service members to help mitigate risk. Additionally, the Amber and Red cohorts are small enough that, given enough resources, they could also benefit from targeted risk mitigation programs. However, the high-risk Black cohort should be a priority based on our results. High-throughput, low-burden (time and money), and clinically meaningful MSKI risk assessments are essential first steps to delivering MSKI risk reduction interventions to those service members at the greatest risk of MSKI.

Other Contributors to Musculoskeletal Injuries

We identified potential MSKI risk factors beyond pain during the movement clearing screens. Older age and greater body mass index were both statistically significant contributors to MSKI risk within our traffic light model; however, these factors both had small adjusted -HRs limiting their clinical significance. Additionally, males had a lower MSKI risk than females, which agrees with prior literature among service members.[40] Finally, a history of MSKI was a significant MSKI risk factor. A prior MSKI history is one of the most observed MSKI risk factors among service members.[41] It is possible that MSKI history is part of the reason service members in our cohort reported pain during a movement clearing screen. However, our VIFs were all less than 5, indicating pain and prior MSKI did not violate the multicollinearity rules. The VIF results strengthen our findings that pain is an important risk factor for MSKI independent of prior MSKI history.

Limitations

Our study is not without limitations. First, we specifically examined a single US Army airborne unit. Service members in our cohort had an array of military occupations, broadly categorized as services and supplies, maintenance and engineering, support and administration, health care, communications and intelligence, and tactical operations (ie, combat arms). Comparable military occupations exist across US Army units; however, our population was unique in that all service members were also paratroopers in addition to the above occupations. Our findings are likely generalizable to other military populations but should be validated in those populations. Second, pain was self-reported, and service members may not have disclosed if they experienced pain during a movement clearing screen. Thus, some service members who experienced pain may have been classified as pain free, yet we still observed a higher MSKI risk in individuals who did report pain. Along with underreporting pain, service members may have underreported their previous and future MSKIs. Service members do not always seek care for the MSKIs; therefore, MSKIs occurring within our 180-day surveillance period may be an underestimate. Finally, we only analyzed pain during movement, which is but 1 aspect of MSKI risk. Comprehensive MSKI risk assessments are required to holistically evaluate individual MSKI risk; regardless, we were still able to identify potential MSKI risk factors that can be addressed through targeted MSKI risk mitigation interventions.

CONCLUSIONS

Service members reporting pain on movement clearing screens are at a greater risk of MSKI than those not reporting pain. Furthermore, individual movement clearing screens were able to differentiate between service members with high versus normal MSKI risk for each body region–specific screen; this demonstrates the need to include a variety of movement clearing screens in comprehensive MSKI risk assessment paradigms. Finally, a progressive increase in MSKI risk occurs as service members report pain on more movement clearing screens. A traffic light model, even with its low discriminative ability, based on pain reported during movement clearing screens can be employed as a decision support tool by anyone to screen for MSKI risk, as it requires minimal training and no clinical or technical expertise. Future researchers should investigate if pain reduction strategies and other injury prevention programs can reduce the risk of MSKIs among service members categorized as high risk.

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FINANCIAL DISCLOSURE

We affirm that we have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript except as disclosed and cited in the manuscript. Any other conflict of interest (ie, personal associations or involvement as a director, officer, or expert witness) is also disclosed and cited in the manuscript.

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