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RELATIONSHIP BETWEEN FUNCTIONAL MOVEMENT SCREEN AND TACTICAL PERFORMANCE

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ABSTRACT

The purpose of this study was to examine relationship between Functional Movement Screen (FMS) and tactical performance, which was indicated by marksmanship and physical fitness test (PFT). Seventy-eight male cadets aged 21-24 yr (height 175.4 ± 5.1 cm, body mass 67.2 ± 5.2 kg) participated in the study. For regular PFT of Korea Military Academy, they performed 2 min push-up and sit-up, pull-up, and 400 m and 3 km run. After FMS was administered, target shooting was executed from the foxhole supported position with 10 bullets in the middle of cadet summer military training in order to assess marksmanship. Statistical significant level was set at $p \leq 0.05$. Statistic significance was found in the relationships between FMS and PFT and between FMS and target shooting. Inline lunge was significantly correlated with 2 min sit-up (r = -0.251), and right shoulder mobility was significantly correlated with target shooting (r = 0.239). The relationship between FMS and PFT seemed to be random and weak when compared with the results of advanced research. The relationship between FMS and target shooting represented that scapular stability and shoulder mobility would be required to maintain steady position and therefore to secure better performance of target shooting.

Keywords: marksmanship, physical fitness test, military, army, movement

INTRODUCTION

Functional Movement Screen (FMS) consists of a) seven-step screening tests: deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), push-up (PU), and rotary stability (RS) and b) three clearing tests: impingement (IC), press-up (PUC), and posterior rocking (PRC). It is the predictive system to screen limitations and asymmetries of movement that affect athletic performance and injury (5). The relationships of FMS with performance (1, 2, 12, 13, 16, 17) and with injury (3, 10, 11, 14, 18) have been studied by many researchers.

Studies about relationship between FMS and athletic performance have shown controversial results on whether the relationship is strong or not (1, 2, 11, 13, 16, 17). McGill et al. (13) and Parchmann and

McBride (17) found no significant relationship between FMS and the performance variables. McGill et al. (13) examined FMS predictability in basketball performance from 14 major American university basketball teams. The performance was defined as number of games played and averages of minutes played, points scored, assists, rebounds, steals, and blocks per game (13). Parchmann and McBride (17) examined relationship between FMS and athletic performance defined as club swing velocity, and physical fitness factors such as 10 m and 20 m sprint time, vertical jump, and T-test in 25 National Collegiate Athletic Association Division I golfers.

Many other studies, however, showed positive results about the relationship between FMS and performance. Lockie et al. (12) examined relationship between FMS and athletic performance defined as physical fitness factors such as multidirectional speed and jumping capability in 22 recreational team sport male athletes. DS was significantly correlated with between-leg 505 difference (r = -0.423), and bilateral vertical jump (r = 0.428) and standing long jump (r = .457) in the study (12). Lockie et al. (12) concluded that DS could be an indicator of athletic performance capabilities with regard to abilities to change direction and also of bilateral jump. Okada et al. (16) examined relationship between FMS and athletic performance defined as physical fitness factors such as backward overhead medicine ball throw (BOMB), T-Run agility test (TR), and single leg squat (SLS). There were significant correlations between BOMB and right SM (r = -0.388), and right RS (r = 0.391), between TR and left ILL (r = -0.462), and right SM (r = 0.392), between SLS and right SM (r = -0.446) (16). Bond et al. (1) studied relationship between FMS and 100 m freestyle swimming performance in 50 national level youth swimmers. FMS was significantly correlated with 100 m freestyle timed swim (r = -0.333) and FMS score difference between fast and slow swimmers group was clear (F = 9.4, p = 0.005). The study concluded that fast swimmers had higher FMS score than slow swimmers (1). Chapman et al. (2) examined athletic performance change during a year between low FMS score (≤ 14) and high FMS score (>14) group in 121 elite track and field athletes. The performance of high FMS score group was significantly promoted compared to the low FMS group (p = 0.03) (2). They concluded that the FMS score is related to longitudinal performance changes in the subjects (2).

FMS is a simple and attractive method to predict performance problem and injury possibility (5) not only of athletics but also of soldiers. Certain physical movements and tactical performance, such as run under load, jump, bound, crawl, lift, carry, throw, and shooting must be required for soldiers (9) to a qualitative and efficient degree for accomplishing mission, and the matter of the highest priority in military circumstances is to accomplish mission without any injury.

Several studies were conducted with regard to the relationship between FMS and injury in military circumstances (6, 11, 14), but few studies were done on the relationship between FMS and tactical performance (11). Lisman et al. (11) examined the relationship between FMS and Marine Corps Physical Fitness Test (PFT) scores in 874 candidates. The pull-ups was significantly correlated with DS (r = 0.10), ILL (r = 0.11), ASLR (r = 0.07), PU (r = 0.09), composite FMS score (r = 0.12). Abdominal crunches were also significantly correlated with DS (r = 0.07), ILL (r = 0.15), and 3-mile run with ILL (r = -0.08).

O'Donoghue (15) well defined main five athletic performance aspects as technique, effectiveness, tactic, movement, and decision-making, but the performance variables can be defined differently from sports to sports. For tactical situation, this study divided tactical performance into two main elements, one for soldiers' fundamental qualifications and another for soldiers' real combat situation: regular PFT and marksmanship. PFT consisted of five tests: three upper body local muscular endurance tests (push-up, sit-up, pull-up), an aerobic (3 km run), and anaerobic (400 m run) fitness tests, and marksmanship was estimated by target shooting hits. PFT of Korea Military Academy is a minimal standard for cadet's physical fitness and combat readiness. All cadets must pass certain cut-point which is different from grade and sex every semester.

The purpose of this study was examining relationship between FMS and tactical performance, which was defined as PFT and marksmanship. Only one rifle marksmanship research was done on determination of relationship between performance on a rifle simulator and actual fire performance on firing range (4). This study will be the first research about relationship between FMS and marksmanship.

METHODS

Experimental Approach to the Problem

The research hypothesis was 'there is significant relationship between FMS and tactical performance.' Tactical performance was delimited and defined as Korea Military Academy PFT and marksmanship in the study. Accordingly, FMS scores, PFT results, and shooting hits were acquired as variables for correlation analysis to test the research hypothesis. In addition, FMS scores were used as independent variables, and tactical performance variables were used as dependent for regression analysis to examine prediction of FMS on tactical performance.

Subjects

Seventy-eight male cadets aged 21-24 yr (height 175.4 ± 5.1 cm, body mass 67.2 ± 5.2 kg) who gave informed consent participated in the study. Subjects were informed of the risks and notified that no disadvantages would happen if they did not participate in the study. Subjects were living in barracks and having a similar daily schedule during a semester when data collection was administered. The study was approved by the chief of Cadet's Corps (Institutional Review Board for Use of Cadet as Subjects).

Procedures

PFT was administered on subjects according to periodical schedule one month before FMS testing. Twelve testers, instructors in physical education department, who had experienced many PFT as a tester at least 5 sessions corresponding over 1,000 cadets for subjects, tested 2 min push-up, 2 min sit-up, and 3 km run in one day, and pull-up and 400 m run in the second successive day. Subjects wore PT uniform, short-sleeved t-shirt, and shorts and took enough rest at least for 20 min between tests.

After PFT, cadets were informed about FMS test through instructors of physical education department at class, and 78 volunteers participated in the test. Instructors did not state about this study in order to minimize measurement errors from subjects. Before this study, 3 testers, one with FMS certification and the others without, administered FMS for practice on 20 other participants who were not subjects in the study, for reliability of assessment. FMS was administered on 78 subjects, wearing PT uniform in 2 days. Each tester tested all 7 step screening and 3 clearing tests on each subject after height and body mass were measured.

Target shooting was administered at 2nd week of cadet summer military training, 3 weeks after FMS test. Subjects had 10 shots in a day from foxhole supported position with 3 shots on 100 m and 250 m each and 4 shots on 200 m target.

2 min push-up. On the signal ‘ready’ from a tester, subjects assumed front-leaning rest position placing palms on push-up bar, which is 25 cm above ground with comfortable shoulder width. Heels should touch each other, and the body should be straight from shoulder to heels. On the signal ‘start,’ subjects did push-up as many as they could for 2 min by bending elbow until upper arms were parallel to the bar with his or her whole body lowered and keeping straight form. Tester counted after whole body was lifted and kept straight form by extending elbow until back to start position. The tester stated the number of repetitions for subjects using counting device. The termination of test occurred during 2 min if subjects could not maintain the previously explained push-up position.

2 min sit-up. On the signal ‘ready’ from a tester, subjects lay on back on sit-up mat with knees bent at 45-degree angle and feet fixed. Palms were placed on the back of the head with fingers locked together. On the signal ‘start,’ subjects did sit-up as many as they could for 2 min by lifting their upper body until their elbows touch their knees while keeping interlocked fingers placed on the back of head. The tester counted after elbows touched knees while keeping the posture stated above. The tester stated the number of repetitions for subjects using counting device. Sit-up was not counted if subject’s shoulder blades did not touch the mat.

3 km run. Track was asphalt road, and distance was measured by measuring tape. On the signal ‘ready’ from a tester, subjects were lined up behind the starting line. In one session, 30 subjects ran at the same time. On the start signal of whistling, subjects began running for 3 km. Time to over finish line was recorded in seconds.

Pull-up. On the signal ‘ready’ from a tester, subjects held the pull-up bar by pronated grip with extended arms. On the signal ‘start,’ subjects lifted their body until their chin moved above the bar without swinging their body for better lifting as many as they could. The tester stated the number of repetitions for subjects using counting device. The termination of test occurred if subjects’ hands fell off from the bar and feet touched the ground. During test, pull-up was not counted if subject’s arms were not fully extended, chin was not lifted above the bar, or their body swung.

400 m run. Subjects ran on the athletic track, 1 lap is 400 m and designed for 8 people to run at the same time. On the signal ‘ready’ from tester, subjects were lined up behind starting line. In one session, 8 subjects ran at the same time. On the start signal of whistling, subjects began running for 400 m. Time to over finish line was recorded in seconds.

FMS. Seven-step screening tests with 3 clearing tests were administered on subjects as described in Cook et al. (1). Subjects received 0 to 3 scores at each screening test, ‘0’ means pain existed and the more score the better performance at each test. Specific scoring standard is different from test to test, and the standard (1) was applied to all subjects. In clearing tests, subjects received ‘positive’ or ‘0,’ ‘0’ means pain existed as same as screening tests, ‘positive’ means no pain existed. In tests, HS, ILL, SM, IC, ASLR, and RS, scored each leg and the lower score was applied as a final score for each test. All testers explained each test to subjects following verbal instructions described in Cook et al. (5) for reliability. Subjects attempted 3 times to perform each test for tester's valid scoring following the instruction of Cook et al. (5).

Target shooting. Subjects practiced preliminary rifle instruction before they performed target shooting in the same environments for the same amount of time, in order to reduce extraneous variable on marksmanship. Firearm was K-2 assault rifle (S&T Motiv, Busan, South Korea), and loaded bullet was 5.56 × 45 mm. Popping-up target shaped of men was 66 × 49 cm for 100 m, 50 × 100 cm for 200 and 250 m plat surface which had a sensor that counts the number of hit directly to a computer (7). The sequence of shooting was 250-100-200-250-100-200-250-200-100-200 m, and available shooting time for subjects were 5 sec for 100, 200 m target and 10 sec for 250 m one (7). Firing on targets was executed in foxhole-supported position. Eight cadets shot at the same time at each lane of fire. On the signal 'ready to fire' from firing range controller, every subject prepared firing with both hands on K-2 rifle aiming on first target point. After the signal 'commence fire' from the controller, firing began according to the sequence stated above. Electronically transmitted scores, the number of hits on target from each subject, were acquired for data analysis.

Statistical Analyses

Means and standard deviations of body mass index (BMI), PFT, shooting hits, and FMS scores were calculated for descriptive analyses. Pearson correlation was used for examining relationships between FMS and PFT, shooting hits. To examine predictive ability of FMS on tactical performance, linear regression technique was used. For further analyses to compare FMS between high and low tactical performance groups that were divided by median, independent t-test was employed. Significant level was set at $p \leq 0.05$ and SPSS (Version 21, SPSS Corp., Armonk, NY, USA, 2012) was used for data analyses.

RESULTS

Average of FMS was 17.0, and subjects whose FMS score was 14 or less were only 7 subjects. Means and standard deviations of BMI, PFT, shooting hits were described in Table 1. Correlations between FMS scores and tactical performance were calculated in Table 2. Two minute sit-up was significantly correlated with left HS (r = -0.241), left ILL (r = -0.340), and ILL (r = -0.251) respectively. Three km run was significantly correlated with right ILL (r = -0.243). Other variables of PFT were not significantly correlated with FMS. Correlations between shooting hits and HS (r = -0.252), left ILL (r = -0.234), and right SM (r = 0.239) were statistically significant.

As HS, left ILL, and right SM were significantly correlated with shooting hits, those variables were included as independent variables for examining relative contributions to the prediction of shooting performance as shown in Table 3.

Right SM had relatively more effect (b = 0.218) on shooting performance than HS (b = -0.183) and left ILL (b = -0.207). Right SM had statistically significant effect on shooting performance when HS, left ILL, and right SM were included as independent variables in multiple regression analysis. Only 14.6 % of the variance in shooting performance was accounted for HS, left ILL, and right SM.

Subjects were divided into high and low tactical performance groups according to median of each variable and were compared between groups. The variable that shows significant difference between groups, pull-up, was described in Table 4.

Median of pull-up was 12. Low performance group included all subjects whose pull-up was below 12, and higher one included subjects whose pull-up was 12 or above. FMS scores between high and low performance group were compared by independent t-test as shown in Table 4. The variables that show significant difference between groups, right ILL and PU, was described in Table 4. The better performance group had the higher right ILL and PU.

Table 1. Descriptive statistics of BMI, PFT, shooting hits, and FMS.

	Mean (*SD*)
BMI (kg/m^2)	21.9 (1.4)
2 min push-up	84.7 (9.9)
2 min sit-up	87.8 (7.4)
3 km run (sec)	703.0 (33.4)
Pull-up	11.6 (4.2)
400 m run (sec)	65.0 (3.0)
Shooting hits	7.0 (1.9)
FMS	17.0 (1.8)

SD : Standard Deviation.

Table 2. Correlations between FMS and PFT, shooting hits

	2 min Push-up	2 min Sit-up	3 km Run	Pull-up	400 m Run	Shooting hits
DS	0.027	-0.028	0.011	-0.059	0.136	0.016
right HS	0.034	-0.090	0.096	0.000	-0.072	-0.217
left HS	-0.059	**-0.241***	0.163	0.052	-0.043	-0.009
HS	-0.015	-0.178	0.221	0.004	0.024	**-0.252***
right ILL	0.129	-0.095	**-0.243***	0.180	-0.044	-0.087
left ILL	-0.054	**-0.340****	0.024	0.119	0.091	**-0.234***
ILL	0.003	**-0.251***	-0.072	0.210	0.016	-0.109
right SM	-0.036	-0.055	-0.052	-0.108	0.059	**0.239***
left SM	-0.096	0.144	-0.052	-0.100	0.170	-0.102
SM	-0.073	0.083	0.078	0.088	0.187	0.105
right ASLR	-0.034	-0.082	0.059	0.019	0.061	0.017
left ASLR	-0.057	-0.091	0.108	-0.011	0.077	0.018
ASLR	-0.002	-0.125	0.087	0.002	0.085	0.028
PU	0.092	-0.143	0.036	0.132	0.018	0.041
right RS	0.040	0.015	0.104	0.053	0.017	0.137
left RS	-0.008	0.050	0.045	0.066	-0.007	0.060
RS	-	-	-	-	-	-
FMS composite	0.023	-0.160	0.106	0.113	0.147	-0.018

Bold * indicate $p \leq 0.05$, Bold ** indicate $p \leq 0.01$, relationship with RS could not be calculated because all subjects had 2 for RS.

Table 3. Analysis of variance table for estimation of shooting performnace from HS, left ILL, and right SM.

	B	Standard Error	beta coefficient (*b*)	*t*	*p*-value
(Constant)	5.898	3.335		1.768	0.081
HS	-0.796	0.482	-0.183	-1.652	0.103
left ILL	-0.988	0.523	-0.207	-1.890	0.063
right SM	1.905	0.952	0.218	2.000	0.049
$R^2 = 0.146$		$F = 4.223$	$p = 0.008$		

Table 4. Comparison of FMS scores between high and low pull-up performance groups.

		Mean (*SD*)	
PFT (mdn)		Right ILL	PU
pull-up (12)	< mdn	2.71(0.46)	2.37(0.82)
	≥ mdn	2.90(0.30)	2.73(0.64)
	p-value	$p = 0.034$	$p = 0.035$

mdn: median.

DISCUSSION

The purpose of this study was to examine relationship between FMS and tactical performance which was defined as marksmanship and PFT. Primary limitation of the study was homogeneous characteristic of subjects, only 7 subjects of 78 (9.0%) had FMS score 14 or less. In Lisman et al. (11) with marine candidates as subjects, the ratio was 10.8%. Schneiders et al. (19) examined normative FMS values in physically active 108 females and 101 males aged 18-40 yrs. In the study, 31 % of subjects had a FMS score of 14 or less which was large compared to the ratio of this study and Lisman et al. (11). The comparison shows subjects under military circumstances have high level of FMS score compared to subjects in other circumstances. All recruited soldiers or cadets must pass certain level of PFT and diverse basic clinical screenings, and therefore the recruiting system would automatically choose person who has a good quality of movement without pain. Due to the homogeneity in the group, the application of the result of this study on other subjects would be limited, and size of relationship might have occurred in lower range.

Marksmanship had statistically significant relationship with right SM (r = 0.239) in a positive direction and with HS (r = -0.252), left ILL (r = -0.234) in a negative way. The results represent that better right SM, poor HS and left ILL help to maintain steady foxhole supported position and therefore to success more hits on target, though cause and effect relationship could not be examined through correlation analysis. The significant relationship between marksmanship and right SM would be partly because of the low percentage of left-hander; only 7 subjects were left-handed.

The relationship between marksmanship and FMS can be explained by each concept's elements and standpoint of human body. Four fundamentals of marksmanship are steady position, aiming, breath control, and trigger squeeze (8). Steady position would be the most important factor among four fundamentals considering its influence on the other three factors. Unsteady and physically limited position might cause incorrect or unstable aiming on target, unstable breath control, and abrupt trigger squeeze. Steady position has 9 elements: non-firing and firing handgrip, rifle butt position, non-firing and firing elbow placement, cheek-to-stock weld, support, muscle relaxation, and natural point of aim (8). The rifle butt should be firmly placed in the pocket of firing shoulder to reduce the effect of recoil when firing (8). Therefore, firing shoulder need to have a good quality of function for maintaining balance when it is shaking from recoil effect, which means to maintain steady non-firing and firing elbow placement on the ground, same spot of cheek-to-stock weld, steady point of aim, and same level from the ground during firing.

Right SM screening was designed to observe pattern of right shoulder's range of motion, combining extension, internal rotation, and adduction, which helps observe extent of scapular stability (5). Significant relationship between marksmanship and right SM indicates that better scapular stability may be required for soldiers to shoot better. Restricted mobility on shoulder (5) can be assumed to cause inefficient movement quality for shooting; a person with excessive muscle especially on pectoralis minor, latissimus dorsi and rectus abdominus might display poor marksmanship. Application of the result might be limited to a soldier in foxhole supported position or in similar firing position, which requires the stability of shoulder, or supporting his or her elbow on the ground.

On the other hand, several previous studies (13, 16) showed relationship between poor SM and better athletic performance. McGill et al. (13) contended that shoulder mobility was not significantly but negatively related with most basketball performance variables defined as games played, minutes per game, points per game, assists per game, rebounds per game, and steals per game. In addition, Okada et al. (16) showed significantly negative relationship (r = -0.388) between BOMB and right SM, which means that poorer right SM is related with better performance of throwing medicine ball. The reason for the negative relationship was not fully explained in both studies. Main type of athletic performance in both studies was throwing movement that may require strength and power of shoulder muscle, whereas shooting requires shoulder mobility and scapular stability to maintain steady position. The difference in the required types of performance might be the reason for the difference between this study and the studies of McGill et al. (13) and Okada et al. (16) in directions of relationship between SM and performance.

The reason for the significantly negative relationships between marksmanship and HS, left ILL is uncertain. Right SM (p = 0.049) was the only meaningful significant prediction variable on shooting performance when all significant variables from relationship analysis were included in multiple regression analysis for estimating shooting performance in Table 3. Both HS and ILL seem to have strong tendency to test patterns of movement while the target shooting is static performance. Thus, there might be very weak connectivity between two variables. For future research, firing position with more movements or of types different from foxhole supported should be examined in its relationship with FMS.

The result of this study was compared to Lisman et al. (11) to examine relationship between FMS and PFT. For comparison analysis, only final FMS score was considered, not right or left side of FMS, because Lisman et al. (11) showed relationship between PFT and final FMS. ILL was significantly but negatively correlated with 2 min sit-up (r = -0.251) in this study, but it was significantly but positively correlated with abdominal crunches (r = 0.150) in Lisman et al. (11). Directions of relationships between FMS variables (DS, ILL, SM, PU, FMS composite) and 2 min sit-up of this study were opposite from those between the same FMS variables and abdominal crunches of Lisman et al. (11). The relationship between FMS and PFT seemed to be random among studies and therefore could not be clarified. This result also supports the weak association between the FMS and PFT in Lisman et al. (11).

Interestingly, however, the higher pull-up performance group had significantly better right ILL and PU than lower pull-up performance group when two groups were divided by median 12 in this study. Lisman et al. (11) also showed significant relationship between pull-up and ILL and PU. This connection between significant group difference and significant relationship suggests that pull-up might require “natural counterbalance the upper and lower extremities, and spine stabilization” considering its relationship with ILL and also require ability to stabilize the spine in the sagittal plane considering its relationship with PU (5).

This study might be the first study that determined relationship between FMS and tactical performance, which was defined as marksmanship and PFT. The study showed statistically significant relationship between right SM and marksmanship, but no significant relationship was found between FMS and PFT.

CONCLUSION

This study has a great significance in that it is a first study of examining relationship between human movement quality and tactical performances. The study would help officers and researchers interested in preparing strong soldier for their country. Its results indicated that better shoulder mobility is significantly related to better marksmanship, though further study would be required to strengthen the evidence. Training of stretching for shoulder mobility should be considered to be included in preliminary rifle instruction. Results also found the weak link between FMS and PFT.

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