Predicting Performance and Injury Resilience From Movement Quality and Fitness Scores in a Basketball Team Over 2 Years

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Abstract

McGill, SM, Andersen, JT, Horne, AD. Predicting performance and injury resilience from movement quality and fitness scores in a basketball team over 2 years. *J Strength Cond Res* 26(7): 1731–1739, 2012—The purpose of this study was to see if specific tests of fitness and movement quality could predict injury resilience and performance in a team of basketball players over 2 years (2 playing seasons). It was hypothesized that, in a basketball population, movement and fitness scores would predict performance scores and that movement and fitness scores would predict injury resilience. A basketball team from a major American university ($N = 14$) served as the test population in this longitudinal trial. Variables linked to fitness, movement ability, speed, strength, and agility were measured together with some National Basketball Association (NBA) combine tests. Dependent variables of performance indicators (such as games and minutes played, points scored, assists, rebounds, steal, and blocks) and injury reports were tracked for the subsequent 2 years. Results showed that better performance was linked with having a stiffer torso, more mobile hips, weaker left grip strength, and a longer standing long jump, to name a few. Of the 3 NBA combine tests administered here, only a faster lane agility time had significant links with performance. Some movement qualities and torso endurance were not linked. No patterns with injury emerged. These observations have implications for preseason testing and subsequent training programs in an attempt to reduce future injury and enhance playing performance.

Key Words movement, torso endurance, strength, fitness testing, basketball

Introduction

The ability to successfully predict injury resilience and competition performance from preseason testing is a very wishful goal; however, questions remain regarding this objective: Do tests of fitness have a predictive ability for injury and are there other factors that can be assessed that may predict injury? Are there specific indicators that predict performance? This study was motivated by these questions.

Attempts to understand injury mechanisms and performance sometimes consider links to fitness. Traditionally, fitness testing, at least in occupational settings, has included the assessment of strength (13), joint range of motion (ROM) (23), and physiological variables such as heart rate, blood pressure, and oxygen uptake (2), but the performance scores in the occupational context are difficult to quantify. In contrast, there have been some studies relating fitness to sporting performance that are more tangible. In studies of ice hockey players (6,24), success could be more tangibly quantified from on-ice measures such as total minutes played and scoring chances. Green at al. stated that "goals scored" was not the best measure of hockey skill. Studies of football players suggest that those who score higher on movement quality tests have few injuries (11,12); however, preseason football combine testing is dominated by tests of strength and running speed. Recognizing that movement asymmetry and compromises to neuromuscular control have been linked to both future injury (11,12) and with having a history of back injury (17), movement assessments have been developed (3,4) and have been suggested to predict injury rates. Further, several fitness and movement tests have been implicitly assumed to predict "playing" performance by their inclusion into standard preseason tests. These include tests of endurance, strength, joint ROM, agility, and speed. The question remains as to the validity of these factors when attempting to predict injury resilience and performance.

Although links between moving well and injury resilience and performance seem intuitive, this notion remains controversial. Interestingly, some evidence suggests that fitness training alone may not ensure peak performance or injury resilience (8,20). In addition, movement quality has been

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26(7)/1731–1739

Journal of Strength and Conditioning Research

suggested to predict future injury (12). A possible mechanism may be that injury changes the way a person moves as an accommodation to pain (consider, e.g., the changes in mechanics throughout the anatomical linkage when limping from foot pain). Having a history of injury, in particular back injury, appears to change movement patterns (17). Movement patterns determine important injury criteria, such as joint and tissue load, together with influencing the length of time and repetitions an individual is able to perform a task with uncompromised form. Compromised form exposes the tissues to inordinate load elevating the risk of injury. Several examples of this link are available, for example, not maintaining a neutral curve in the lumbar spine while bending and lifting decreases the tolerable load at injury (in this case tissue failure [18]); having restricted hip motion is linked to having more spine motion when bending (17). Movement competency has also been linked with anterior cruciate ligament (ACL) injury rates, for example, having larger knee abduction moments and angles when landing from a jump predicted higher ACL injury rates (9). Given the variety of considerations for interpreting the links between movement, fitness, performance, and potential injury, the goal of this study was to first evaluate some traditional fitness test scores in a controlled athletic group that has a variety of challenging movement demands and also perform an assessment of the quality of movement. It was hoped that following a test group for a period of time would reveal links between specific fitness scores and movement quality with variables to predict injury resilience and performance. If such links exist, they could form a rationale for specific tests to be included in preseason testing.

The purpose of this study was to see if specific tests of fitness, and movement quality, could predict injury resilience and performance in a team of basketball players over 2 years (playing seasons).

It was hypothesized that in a university basketball population, (a) Preseason movement quality and fitness scores would predict in-season performance scores. (b). Preseason movement quality and fitness scores would predict in-season injury resilience.

Methods

Experimental Approach to the Problem

Members of a varsity basketball team from a major American university were recruited ($N = 14$). The participants took part in 3 days of preseason testing that evaluated movement competency (day 1); speed, agility, and on-court basketball skills (day 2) and variables of torso endurance, strength, hip ROM (day 3). Each session lasts approximately 45 minutes each day. Performance data and injury reports were tracked for the subsequent 2 years.

Subjects

Male athletes, all members of a varsity basketball team, volunteered to participate. Their mean age: 20.4 years (*SD* 1.6); height: 197.3 cm (*SD* 9.4); and weight: 95.3 kg (*SD* 10.5) were collected at the beginning of the first basketball season. Each participant read and signed an informed consent document approved by the University Office for Research Ethics.

Procedures

Movement Competency. Movement competency was assessed with 20 general tasks. Seven comprised the Functional Movement Screen (tasks 1–7) and were administered with specific instructions (3,4). The remaining 13 movements were chosen to reflect tasks often used by clinicians or Kinesiologists to evaluate injury risk or return to work status. The 20 tasks were as follows: (a) Deep squat–A dowel was placed overhead with the arms outstretched as the individual squatted as low as possible. (b) Hurdle step–A dowel was placed across the shoulders and the individual stepped over a hurdle (tibial tuberosity height) placed directly in front of them. (c) In-line lunge–With the feet aligned and a dowel contacting the head, upper back, and sacrum, the participant performed a split squat. (d) Shoulder mobility–The individual attempted to touch their fists together behind their back (internal and external shoulder rotation). (e) Active straight leg raise–While lying supine on the ground, the individual actively raised one leg as high as possible while the other leg remained in contact with the ground. (f) Trunk stability push-up–The participant performed a push-up with their hands shoulder width apart. (g) Rotary stability–The individual assumed a quadruped position and attempted to touch his knee and elbow, first on the same side of the body and then on the opposite. "Clearing" tests were included with the SHDR, PUSH, and ROT tasks to expose other potential sources of pain (3,4). (h) Standing posture–The participant stood in a relaxed position with his arms at the side. (i) Seated posture–The participant sat on a box (0.40 m in height) in a relaxed manner with his arms on his lap. (j) Segmental flexion–From standing, the individual bent forwards as far as was comfortable. (k) Segmental extension–From standing, the individual bent backwards, reaching over head with their arms, as far as was comfortable. (l) Segmental lateral bend–From standing, the individual bent laterally as far as was comfortable. (m) Segmental twist–From standing, the individual twisted about the hips and spine as far as was comfortable. (n) Gait–The participant walked 10 paces. (o)Box lift–From standing, a light-weight (~2 kg) box ($0.33 \times 0.33 \times 0.28$ m) was lifted to waist height and returned to the ground. (p) Coin lift–From standing, a coin was picked up off the floor. (q) Single leg deadlift–The individual balanced on one leg with a dowel in his hands and bent over as far as was comfortable. (r) Single leg squat–The individual balanced on one leg and squatted down as low as was comfortable. (s) Torsion control–While bridging off the floor (hands and toes), one arm was lifted off the ground. The task was also performed by lifting each leg off the ground. (t) Pelvis rock–Beginning in a quadruped position, the individual rocked his pelvis back toward his heels while keeping the hands on the ground.

Torso Endurance. Sit-up posture–The participants adopted a sit-up posture with the knees and hips flexed and the arms folded across the chest. The back (neutral spine–spine curvature similar to that when standing) was placed against a box angled 60° from the floor. The test began when the box was pulled away from the back and ended when a neutral spine posture could no longer be maintained. The feet were secured for the duration of the test (16).

Front plank–Beginning in a prone position, the participants lifted themselves off the ground with their elbows and toes. The test began with a neutral spine position (a similar spine curvature to a standing position) and ended when the position could no longer be held.

Beiring-Sorensen extension–The upper-body was cantilevered over the end of a bench with the pelvis (anterior superior iliac spine) in line with the edge of the bench. The knees and hips were secured. The test began with the participant supporting his own upper-body mass and the arms positioned across the chest, while a straight-body position was held. The test ended when the horizontal position could no longer be maintained.

Right and left side plank–The participants were placed in a side lying position and asked to raise themselves off the floor with their elbow and feet (the top foot was placed in front of the bottom foot). The test began once a straight-body position was attained with a neutral spine and ended when the position could no longer be held. This test was performed on both the right and left sides.

Strength. Grip strength–Sitting in a chair with no arm rests, the participant's shoulder was adducted at zero degrees of flexion, the elbow flexed to 90° and the wrist placed in a neutral position (7). A hand dynamometer (Takei Kiki Kogyo, Nigata, Japan) was used to record a maximal effort with each hand. This served as an absolute measure of strength, recorded in kilograms.

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

Bench press (as per the National Basketball Association [NBA] Combine Test)–The participants warmed up with 10 push-ups, followed by 60 seconds of rest, and 5 bench press repetitions of 135 lbs (61 kg). After an additional 90 seconds of rest, individuals performed their maximum number of bench press repetitions with 185 lbs (84 kg). A legal repetition was only counted if arms were fully locked at the top and the bar touched the chest at the bottom. The individual's buttocks must have stayed in contact with the bench.

Hip Range of Motion. Hip extension (knee flexed)–Lying supine with the nontest leg's hip and knee flexed (i.e., Thomas test position), the researcher ensured that the spine was in a neutral position. The test leg's knee was flexed to 90° and lowered passively. Hip extension was recorded as the angle between the horizontal (0°) and a line between the greater trochanter and the lateral epicondyle of the femur (a more negative angle was associated with greater ROM), measured with an orthopedic goniometer. This test was performed for both the right and left legs.

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

Hip flexion (knee flexed)–Lying supine on a bench with a neutral spine and the nontest leg fully extended, the test leg was placed in 90° knee flexion and raised by the researcher until spine motion was noted. Hip flexion was recorded as the angle between the horizontal (0°) and a line between the greater trochanter and the lateral epicondyle of the femur. This test was performed for both the right and left legs.

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

Hip internal rotation–Lying prone, the hips were placed at 0° abduction and the test knee was flexed to 90°. The researcher passively guided the hip into internal rotation and a measurement was taken between the vertical (0°) and the shank.

Hip external rotation–Lying prone, the hips were placed at 0° abduction and the test knee was flexed to 90°. The researcher passively guided the hip into external rotation and a measurement was taken between the vertical (0°) and the shank.

Speed and Agility. Long jump distance–Standing with feet shoulder width apart, the participants performed a 2-footed horizontal long jump. The length of the jump was measured in centimeters from the front of the toes at take-off to the back of the heels upon landing. The average of 3 jumps was recorded as the individual's score.

Three bounds jump–Standing on their dominant leg, the participants performed 3 successive single-legged horizontal jumps. The length of the jump was measured in centimeters from the front of the toes at take-off to the back of the heels upon landing the third jump. The average of 3 jumps was recorded as the individual's score.

Shark time–In the middle square of a 3 by 3 grid, the participants stood on their dominant leg and performed single-legged jumps to each outside square, returning to the center square after each excursion. Time was measured from a "go" signal to when the individual returned to the center square after jumping to each outside square.

Speed get-up test–From a prone position with hands at shoulder level on the ground and nose to the floor, the participants were instructed to stand up as quickly as possible. Time was measured from a "go" signal to the point when

TABLE 1. Pearson product moment correlation of performance variables with measures of torso endurance and strength.*

		Situp posture (s)	Front plank (s)	Beiring-sorenson (s)	Right side plank (s)	Left side plank (s)	Right grip strength (kg)	Left grip strength (kg)	Pull-ups (repetitions)	Bench press (repetitions)
Games played	*R*	−0.08	0.25	0.14	−0.07	−0.20	−0.29	−0.42	0.21	0.05
	Alpha	0.77	0.40	0.63	0.82	0.48	0.32	0.13	0.48	0.86
Minutes per game	*R*	0.04	0.05	0.01	0.03	−0.24	−0.26	**−0.565**†	0.17	0.02
	Alpha	0.91	0.88	0.97	0.92	0.41	0.37	**0.04**	0.55	0.94
Points per game	*R*	0.29	0.03	−0.10	−0.09	−0.32	−0.39	−0.03	0.23	−0.35
	Alpha	0.32	0.91	0.73	0.75	0.27	0.17	0.93	0.44	0.22
Assists per game	*R*	0.33	0.08	−0.06	0.16	−0.20	−0.14	*−0.49*	0.10	−0.37
	Alpha	0.25	0.79	0.84	0.60	0.49	0.64	*0.07*	0.73	0.20
Rebounds per game	*R*	−0.14	−0.09	−0.19	−0.01	−0.25	−0.24	**−0.550**†	0.09	0.23
	Alpha	0.64	0.76	0.52	0.98	0.38	0.41	**0.04**	0.76	0.43
Steals per game	*R*	0.15	0.10	0.10	0.16	−0.12	−0.22	**−0.607**†	0.10	−0.22
	Alpha	0.62	0.73	0.74	0.60	0.69	0.45	**0.02**	0.72	0.45
Blocks per game	*R*	−0.29	−0.06	−0.38	−0.18	−0.08	−0.08	−0.26	0.18	**0.589**†
	Alpha	0.31	0.83	0.19	0.55	0.77	0.79	0.37	0.53	**0.03**

*Bold entries are statistically significant.
†($p < 0.05$). Italicized data approach statistical significance ($p < 0.10$).

the individual was standing upright. The strategy used by each individual (i.e., squat, lunge or other) was noted. The average of 3 trials was recorded as the individual's score.

Unconstrained lunge–Standing with feet shoulder width apart, the participants were asked to perform a lunge while keeping the torso in an upright position. No other instructions were given. The researcher noted if lumbar flexion was present. The individual was given a score of 0 (cannot perform or experiences pain), 1 (perform with multiple compensations but no pain), 2 (perform with one compensation without pain), or 3 (performed with no compensations or pain).

Three minute Celtic Run–Participants started in a 2-point stance behind the baseline on a basketball court and ran baseline to baseline as many times as they could in 3 minutes. Their score was recorded as the number of full repetitions they completed of one court length.

National Basketball Association Combine Testing. No step vertical jump–From a standing position with feet shoulder width apart, participants performed a 2-footed vertical jump. The height of the jump was measured in centimeters from a standing vertical reach to the highest point the individual could touch with one hand with the jump.

Lane agility drill–Cones were placed at the 4 corners of the key on a basketball court (2 at the right and left corners of the free throw line and 2 at the right and left hand corners of the baseline). Standing at the left hand corner of the free throw line facing the baseline, the participants would sprint forward to the first cone at the baseline, side step right to the second cone at the baseline, run backward to the third cone at the free throw line, side step left to the fourth cone at the free throw line (at the start position), change directions to side step to the right back to the third cone, sprint forward to the second cone, side step left to the first cone, and finish by backpedaling to the fourth cone at the original start position. Time was measured from the individual's first movement to when they completed the drill. An average of 2 trials was recorded as the individual's score.

Three quarter court sprint–The participants started in a 2-point stance behind the baseline on a basketball court. They sprinted to the opposite free throw line as quickly as possible. Time was measured from the individual's first movement to when they crossed the opposite free throw line. An average of 2 trials was recorded as the individual's score.

Performance and Injury Reports. Measures of performance included number of games played throughout the season

TABLE 2. Pearson product moment correlation of performance variables with hip range of motion.*

		Left hip extension −knee flexed	Right hip extension −knee flexed	Right hip extension −knee extended	Left hip extension −knee extended	Right hip flexion−knee flexed	Left hip flexion−knee flexed	Right hip flexion−knee extended	Left hip flexion−knee extended	Right internal hip rotation	Left internal hip rotation	Absolute hip rotation asymmetry	Right external hip rotation	Left external hip rotation	Absolute external hip rotation asymmetry
Games played	*R*	−0.14	−0.17	−0.14	−0.26	−0.43	−0.36	−0.16	−0.21	−0.12	−0.09	−0.15	0.05	0.16	0.08
	Alpha	0.63	0.56	0.64	0.37	0.12	0.21	0.59	0.47	0.68	0.76	0.60	0.87	0.59	0.79
Minutes per game	*R*	0.07	0.02	0.11	−0.11	−0.25	−0.19	0.19	0.10	−0.03	0.10	−0.15	0.05	0.24	0.15
	Alpha	0.81	0.94	0.71	0.70	0.39	0.51	0.53	0.74	0.92	0.73	0.62	0.86	0.41	0.60
Points per game	*R*	0.24	0.31	0.40	0.33	−0.33	−0.21	0.03	−0.06	0.13	0.08	0.01	0.24	0.19	0.23
	Alpha	0.41	0.29	0.16	0.25	0.24	0.48	0.93	0.85	0.67	0.79	0.97	0.41	0.52	0.43
Assists per game	*R*	0.20	0.23	0.19	0.03	0.04	0.09	0.08	−0.02	0.15	0.13	−0.32	0.06	0.00	0.45
	Alpha	0.49	0.43	0.52	0.91	0.89	0.76	0.79	0.95	0.61	0.65	0.26	0.84	0.99	0.11
Rebounds per game	*R*	−0.02	−0.07	0.04	−0.15	−0.40	−0.40	0.39	0.29	0.11	0.21	−0.13	0.02	0.34	0.01
	Alpha	0.93	0.80	0.90	0.61	0.15	0.16	0.17	0.31	0.71	0.47	0.65	0.95	0.23	0.96
Steals per game	*R*	0.07	0.03	0.03	−0.17	0.04	0.08	0.06	−0.04	−0.11	−0.03	−0.28	0.03	0.08	0.30
	Alpha	0.81	0.92	0.92	0.56	0.90	0.78	0.84	0.89	0.71	0.91	0.33	0.92	0.79	0.30
Blocks per game	*R*	−0.31	−0.39	−0.16	−0.23	**−0.743**‡	**−0.736**‡	**0.545**†	0.45	0.00	0.30	−0.16	−0.17	0.32	−0.20
	Alpha	0.28	0.17	0.58	0.42	**<0.01**	**<0.01**	**0.04**	0.11	1.00	0.29	0.58	0.55	0.27	0.50

*Hip range of motion variables were measured in degrees. Bold entries are statistically significant (†<0.05, ‡<0.01).

Table 3. Spearman rank order correlation of performance variables with movement tasks.*

		Standing posture	Seated posture	Gait	Segmental flexion	Segmental extension	Segmental lateral bend	Segmental twist	Overhead squat
Games played	*R*	0.45	0.03	−0.04	−0.42	−0.26	*−0.49*	**−0.602**†	−0.31
	Alpha	0.10	0.93	0.90	0.14	0.36	*0.08*	**0.02**	0.29
Minutes per game	*R*	0.41	−0.10	0.04	−0.38	−0.22	**−0.564**†	−0.46	−0.25
	Alpha	0.15	0.73	0.90	0.18	0.46	**0.04**	0.10	0.39
Points per game	*R*	0.23	−0.13	−0.13	*−0.51*	−0.15	−0.34	−0.46	−0.31
	Alpha	0.43	0.67	0.66	*0.07*	0.62	0.23	0.10	0.28
Assists per game	*R*	0.28	0.15	0.15	−0.19	−0.07	−0.36	*−0.48*	−0.18
	Alpha	0.32	0.60	0.61	0.53	0.82	0.21	*0.09*	0.55
Rebounds per game	*R*	0.37	−0.25	0.06	−0.38	−0.32	**−0.564**†	*−0.52*	−0.08
	Alpha	0.19	0.38	0.85	0.18	0.26	**0.04**	*0.06*	0.78
Steals per game	*R*	0.46	0.15	0.37	−0.15	0.00	−0.39	−0.31	−0.12
	Alpha	0.10	0.60	0.19	0.62	1.00	0.16	0.28	0.68
Blocks per game	*R*	0.50	−0.36	−0.32	−0.39	−0.32	−0.29	−0.33	−0.22
	Alpha	0.07	0.21	0.27	0.16	0.26	0.31	0.24	0.44

	In-line lunge	Hurdle step	Box lift	Coin lift	Deadlift	Single leg squat	Straight leg raise	Shoulder mobility	Push-up	Torsion control	Rotary stability	Pelvic rock
Games played	0.01	0.46	−0.29	−0.19	−0.10	−0.01	0.15	−0.25	0.20	0.45	0.22	0.08
	0.98	0.10	0.31	0.51	0.72	0.98	0.60	0.38	0.49	0.11	0.46	0.78
Minutes per game	0.03	0.38	−0.25	−0.31	−0.03	−0.10	0.15	−0.18	0.14	0.44	0.14	−0.02
	0.91	0.18	0.39	0.28	0.93	0.74	0.61	0.53	0.63	0.12	0.63	0.93
Points per game	−0.13	0.45	−0.43	−0.23	−0.10	−0.07	0.07	−0.02	0.08	0.21	0.14	−0.19
	0.65	0.11	0.12	0.44	0.73	0.82	0.80	0.95	0.79	0.47	0.63	0.52
Assists per game	0.16	0.41	−0.27	−0.32	0.03	−0.10	0.24	−0.14	0.26	**0.598**†	0.40	0.08
	0.58	0.14	0.35	0.27	0.93	0.74	0.41	0.64	0.37	**0.02**	0.16	0.78
Rebounds per game	0.04	0.45	−0.38	−0.24	−0.05	−0.37	0.13	−0.11	0.00	0.32	0.05	0.12
	0.89	0.11	0.18	0.40	0.86	0.19	0.66	0.71	0.99	0.27	0.87	0.69
Steals per game	0.16	0.41	−0.09	−0.38	−0.03	−0.08	0.30	−0.27	0.25	**0.542**†	0.23	0.13
	0.58	0.14	0.76	0.18	0.93	0.79	0.30	0.34	0.40	**0.05**	0.42	0.67
Blocks per game	−0.06	0.35	−0.36	0.23	−0.36	−0.16	−0.43	0.14	−0.16	0.04	−0.10	−0.01
	0.84	0.22	0.20	0.42	0.21	0.58	0.12	0.64	0.60	0.89	0.75	0.97

*Bold entries are statistically significant (†$p < 0.05$, ‡$p < 0.01$). Italicized data approach significance ($p < 0.10$).

TABLE 4. Pearson product moment correlation of performance variables with measures of agility.*

		Long jump (cm)	Three bound jump (cm)	Shark time (s)	Get-up time (s)	Vertical jump (cm)	Lane agility time (s)	Court sprint time (s)	Celtic run (repetitions)
Games played	*R*	*0.49*	−0.14	−0.01	0.23	0.26	−0.43	−0.03	0.19
	Alpha	*0.08*	0.63	0.97	0.42	0.37	0.13	0.93	0.51
Minutes per game	*R*	**0.567**†	0.15	0.01	0.07	0.39	−**0.594**†	−0.06	0.29
	Alpha	**0.03**	0.61	0.98	0.82	0.17	**0.03**	0.83	0.32
Points per game	*R*	0.20	0.15	−0.05	−0.09	0.15	−**0.598**†	−0.04	0.34
	Alpha	0.50	0.60	0.87	0.76	0.61	**0.02**	0.90	0.23
Assists per game	*R*	0.34	0.04	−0.10	−0.26	0.36	−**0.741**‡	−0.19	*0.50*
	Alpha	0.23	0.89	0.72	0.38	0.20	<**0.01**	0.50	*0.07*
Rebounds per game	*R*	**0.625**†	0.25	0.03	0.11	0.28	−0.44	0.07	0.18
	Alpha	**0.02**	0.40	0.92	0.72	0.33	0.12	0.80	0.55
Steals per game	*R*	0.52	0.06	−0.04	−0.12	*0.51*	−**0.690**†	−0.25	0.34
	Alpha	0.06	0.85	0.88	0.69	*0.06*	**0.01**	0.38	0.23
Blocks per game	*R*	**0.553**†	0.37	−0.17	0.27	0.10	−0.07	0.23	0.04
	Alpha	**0.04**	0.20	0.56	0.35	0.73	0.80	0.42	0.89

*Bold entries are statistically significant (†$p < 0.05$, ‡$p < 0.01$). Italicized data approach significance ($p < 0.10$).

and averages of minutes played, points scored, assists, rebounds, steals, and blocks per game. Injuries and number of games and practices missed because of injury were recorded throughout the season as well.

Statistical Analyses

Scores on the preseason tests were evaluated for relationships to performance: Those scores with a continuous ratio scale (e.g., grip strength in kilograms) were assessed with a Pearson product moment correlation while scores with an ordinal scale (e.g., movement competency scored with the 0–3 system) were assessed with a Spearman rank order correlation. Correlations were considered significant at the 0.05 level.

Only back injuries sufficient to miss game play were considered in this study. Means on preseason test scores from athletes who did not encounter back injuries were compared those from athletes who did. Preliminary *t*-tests were done to investigate which variables may show the greatest differences between these 2 groups; however, there was only one test where the groups differed significantly.

RESULTS

First correlations are reported between performance variables, followed by links between performance variables and fitness and movement variables and finally links between injury and fitness and movement variables.

Links Between Performance Variables

Minutes played was highly linked with assists ($r = 0.81$, $p < 0.001$), rebounds ($r = 0.92$, $p < 0.001$), and steals ($r = 0.89$, $p < 0.001$) suggesting that opportunity may influence these results (Table 1.). Interestingly, blocks appear to be a unique ability with significant links only to rebounds ($r = 0.76$, $p < 0.002$).

TABLE 5. Performance variables from players who suffered from back injuries and those who did not.

	Suffered back injury		No back injury	
	Mean	*SD*	Mean	*SD*
Games played	28.60	9.29	21.89	12.14
Average minutes per game	21.72	11.63	12.84	13.14
Points per game	6.02	4.17	6.16	7.37
Assists per game	0.84	0.50	0.91	1.34
Rebounds per game	3.16	2.61	1.66	1.60
Steals per game	0.67	0.34	0.48	0.61
Blocks per game	0.59	0.98	0.08	0.09

Links Between Performance and Fitness and Movement Variables

No measure of torso endurance correlated with any performance variable (Table 2). Left grip strength correlated negatively (meaning a weaker grip strength) with minutes played ($r = -0.57$), rebounds ($r = -0.55$), and steals ($r = -0.61$) per game; however, there were no performance links to right grip strength. Bench press correlated with blocks per game ($r = 0.59$) (Table 2) but with no other variable. The only links between performance and hip ROM were between blocks per game and right and left hip flexion with the knee flexed ($r = -0.74$ for both right and left hips) and right hip flexion with the knee extended ($r = 0.55$) meaning more hip ROM was linked to better performance (Table 2). Of the movement competency variables, segmental lateral bend was negatively correlated with minutes ($r = -0.56$) and blocks ($r = -0.56$) per game, as was segmental twist with number of games played ($r = -0.60$) (Table 3). All these negative correlations imply that less mobility in the torso, or more torso stiffness, are linked to better performance. Torsion control was positively correlated with assists ($r = 0.60$) and steals ($r = 0.54$) per game (Table 3). Notably movement competency in the in-line lunge, hurdle step, box, and coin lift, single leg squat, shoulder mobility, push-up, and rotary stability showed no links. Tests of power and agility (Table 4) showed the long jump and Lane agility time to be the most closely linked to performance. For example, Long jump scores correlated with: minutes ($r = 0.67$), rebounds ($r = 0.63$), and blocks ($r = 0.55$) per game. Lane agility time correlated negatively with minutes ($r = -0.59$), points ($r = -0.60$), assists ($r = -0.74$), and steals ($r = -0.69$) per game, meaning that a faster time was linked to more performance (Table 4). Vertical jump did not correlate with any variable below $p < 0.05$.

Injury Reports

Throughout the competitive season, 5 individuals suffered from back injury. There were no test variables or group of variables that could predict back injury within this population. The back injury group was slower in the speed get-up test by 0.18 seconds ($t = 2.3$, $p = 0.038$); however, both groups scored similar on all other tests. One trend that arose was that the back injured group had, on average, played more games and more minutes per game and had a greater number of rebounds and steals per game but not more assists or points scored (Table 5).

Discussion

The data sets of this small study support the first hypothesis in that some preseason movement quality and fitness scores were linked with in-season performance scores. There were some general observations and perhaps surprises. First it appears that stiffer torso's and more mobile hips are linked with performance. This notion has been reported before as the concept of proximal stiffness enhancing distal mobility, which has been linked to performance enhancement in throwing tasks (10) and in mixed martial arts striking (16). The links between different performance variables may suggest that playing more presents more scoring opportunities or that better players play more. The correlation between weaker grip strength on the left hand and higher rebounds, steals and minutes played may need consideration. It is unlikely that hand dominance influenced this relation because the correlation was obtained with each single hand strength and the performance variables. Further, the magnitudes in grip strength were quite similar between right (mean 52 kg [*SD* 9]) and left (50 kg [*SD* 7]) hands. The second hypothesis that movement and fitness scores will predict injury resilience will need more time, and injury observation, to converge on a conclusion. Only 5 injuries were observed, but it is interesting that those getting injured played many more minutes per game, had double the rebounds and fivefold more blocks.

There is little published data on basketball players with which to compare with the results of this study. The NBA combine testing comprises tests of upper-body strength, speed, agility, and jump height. The data in this study provide some guidance into which tests may be most predictive of performance. Examples from other sports suggest there is little support for many of the current preseason tests. For example, Kuzmits and Adams (14) found that only a few selected tests from the NFL combine were predictive of draft order, which was used as a measure of performance, from 1999 to 2004. They concluded that there were no significant trends that could substantiate combine testing as a predictive tool for performance. Similar findings were reported by McGee and Burkett (15). A common concern these authors raised, with respect to the NFL combine, was that the tests may not have been specific enough to game play. Some tests are similar to sport-related skills; however, they lack a game-specific context. For example, sprinting ability is an asset in football, though a 40-yard sprint is uncommon. The highest average yards gained per game in one season by a running back in the NFL was 8.45 yd (21). A study of rugby players (5) supports this notion, as measures of running agility and short distance running speed (i.e., 10 and 20 m) correlated more with measures of performance than did muscle power. A study on 153 elite hockey players completing the NHL combine testing found that standing long jump was a significant predictor of draft selection order together with peak anaerobic power and with a body index incorporating height, weight, and muscular development (1). Interestingly, Peyer et al. (22) also assessed the performance of a single hockey team using similar correlational approaches as this study. They found that leg press, numbers of chin-ups, bench press, and repeated sprint performance were best linked to plus/minus goals scored for and against as the performance criterion measure.

Limitations for interpreting the data of this study include the relatively small study population. Despite the small sample size, significant correlations were observed. Although one may be concerned with the number of correlations reducing the power, the significant results formed clusters around specific variables. For example, in Table 4, performance variables were strongly related to the land agility time with p values of 0.03, 0.02, <0.00, and 0.01 suggesting that a loss of power from multiple correlations, and that these observations occurred by change, is extremely remote. Although links to performance are quite robustly supported, links with injury were not simply because of only 5 observations. Nonetheless this approach acts as an exploratory tool to develop relationships between variables for future study. From this perspective, this study must be regarded as a preliminary study, the compromise being just a single team but the strength being a 2-year observation period. Nonetheless, the data and general conclusion are quite similar to another study conducted on a much larger group elite task police officers (19).

In conclusion, it appears that preseason tests of fitness and movement quality may predict some aspects of in-season performance but the question of whether injury can be predicted remains. This study on a small group over a 2-year period has identified some possible relationships that may be incorporated into larger future studies. This test population will be studied for a number of years to see if any links exist over the longer term.

Practical Applications

Predicting better performance in basketball appears to be linked with having a stiffer torso, more mobile hips, weaker left grip strength, and a longer standing long jump, to name a few. More data are needed to fully assess whether preseason tests are able to predict injury patterns.

Acknowledgments

The authors acknowledge funding assistance from the Natural Sciences and Engineering Research Council of Canada, together with Keke Lyles for his recording and help with injury and performance tracking at Northeastern University. The authors have no conflicts of interest. The results of the present study do not constitute endorsement of the product by the authors or the National Strength and Conditioning Association. This study was approved by the University Office for Research Ethics and conducted at Northeastern University.

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