

A nine-test screening battery for athletes: a reliability study

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Studies have shown that reduced neuromuscular control or strength increases the risk of acute injuries. It is hypothesized that a non-functional movement pattern can predispose for injuries. In the present paper a detailed description of a test battery consisting of nine different tests to screen athletic movement pattern is provided. The aim was to evaluate the inter- and intra-rater reliability of the test battery on a group of male elite soccer players. Twenty-six healthy elite soccer players (17–28 years) were screened. Eighteen participated at a second occasion 7 days later. No significant difference ($P = 0.31$) was found between test occasion 1 (LS means

18.3, 95% confidence interval 14.9–21.7) and test occasion 2 (18.0, 14.4–21.7) in the mean total score of the test battery. No significant difference in the inter-rater reliability was found between the eight physiotherapists at the two test occasions. The intra-class correlation coefficient was 0.80 and 0.81, respectively. The test battery showed good inter- and intra-rater reliability. The screening battery is easy to use for familiarized professionals and requires minimal equipment. However, further studies are needed to confirm the validity of the test battery in injury prevention, rehabilitation and performance enhancement.

Overuse and acute injuries are often seen in sports (Hewett et al., 2005; Engebretsen et al., 2008; Steffen et al., 2008; Ljungqvist et al., 2009). Studies have indicated that some aspects of neuromuscular control (the ability to control movements through coordinated muscle activation) (Williams et al., 2001), such as reduced balance or strength increases the risk of acute injuries such as ankle or knee sprains, as well as muscle strains (Söderman et al., 2001; Arnason et al., 2004; Häggglund et al., 2006; Zazulak et al., 2008). It is hypothesized that a non-functional movement pattern can predispose for injuries (Lehance et al., 2009; Kiesel et al., 2009). In addition, earlier research has suggested that decreased range of motion, anatomical asymmetry, insufficient core stability as well as reduced neuromuscular control can increase the risk of overuse injuries (Leetun et al., 2004; Kibler et al., 2006; Magnus & Farthing 2008; Hibbs et al., 2008; Borghuis et al., 2008).

Assessing the quality of movement patterns is challenging. In the clinical setting, physiotherapists often meet athletes with an established muscular or joint dysfunction. The purpose of examination and testing is to identify where pain or dysfunction originates, in order to prescribe specific treatment to re-establish

normal patterns. Physiotherapists usually meet the athlete, perform an examination in order to detect a non-functional movement or pain pattern, and then treat the patient. A better alternative would be to screen the athlete and search for dysfunctional movement patterns before any pain or functional problems have occurred (Arnason et al., 2004). Functional screening with intervention has shown to change fundamental movement characteristics among soccer players with asymmetries (Kiesel et al., 2009). In this context, sensitive tools with appropriate methodology to detect individual weak links (reduced range of motion, strength, instability or insufficient neuromuscular control), reveal functional limitations and asymmetries, are needed (Bahr, 2009).

Gray Cook (2004) and Minick et al. (2010) have described a seven test battery aiming to identify, analyze and treat functional imbalances in order to improve performance and prevent injuries. In addition, the United States Tennis Association USTA high-performance profile (HPP) is a screening system developed to assess movement patterns considered important for normal function and performance among tennis players. The purpose of the USTA, HPP is to highlight strength and/or flexibility deficits

and identify areas where players should focus their physical training. Throughout the previous 5–10 years a combination of parts from Grey Cooks test battery and the USTA HPP tests have been used, tested and modified for athletes in a clinical practice by our research group. Altogether seven tests were chosen from the two different test batteries and two tests were added to challenge dynamic performance of the trunk flexors and rotation of the spine.

These nine tests were to represent a promising tool for screening athletes. However, its reliability has not been studied. In the present paper we provide a detailed description of a nine-test battery to screen athletic movement pattern and the specific criteria for each test. The aim of the study was to evaluate the inter- and intra-rater reliability of the test battery on a group of male elite soccer players.

Material and methods

Study Design

The subjects were tested on two occasions separated by 7 days. On each occasion the subjects were assessed using a test battery consisting of nine different exercises. Each exercise was repeated three times with no rest in between. The present study took place in February 2009 at the Swedish National Sport Confederation Center.

Athletes

Healthy male elite soccer players of two elite soccer teams were included through contact with the fitness coach. Twenty-six players from the two teams were available for this study, 18 completed the re-test. Eight participants dropped out due to illness and injuries between the two test occasions. The median age of the players included was 18 (range: 17–28), the mean height was 1.84 m [mean and standard deviation (SD) 0.07] and the mean weight was 76.2 kg (SD 8.5). The Swedish ethical committee considered the study as a clinical quality study and a full ethics review was therefore not necessary. All players signed an informed consent form before participation.

Physiotherapists

Eight physiotherapists who were well educated and familiar with the test battery did the assessments, all working in the same clinic (Table 1).

A nine-test screening battery

The nine-test screening battery consists of functional and complex movement exercises (Figs 1–9, for a detailed description of the exercises) picked from different test batteries that have been tested and retested for 10 years. Six tests with modified criteria were picked from the functional movement screen (FMS) (Cook, 2004), The one-legged (Fig. 2) squat, from the USTA HPP and two, the straight leg raise test (Fig. 5) and the seated rotation test (Fig. 8), have been standardized by our research group and used for many years. These two tests were included in the test battery to fill a gap for tests challenging dynamic trunk flexors and rotation of the spine. For the tests, chosen from the FMS, the criterion for the deep squat (Fig. 1) was changed to be performed barefoot instead

Table 1. Information regarding the eight participating physiotherapists

Physiotherapist	Years working with elite athletes	Years experience with FMS	FMS tests performed (n)
1	10	5	800
2	12	7	300
3	10	7	300
4	10	7	300
5	2	3	100
6	6	2	50
7	5	4	500
8	4	3	150

FMS, functional movement screening.

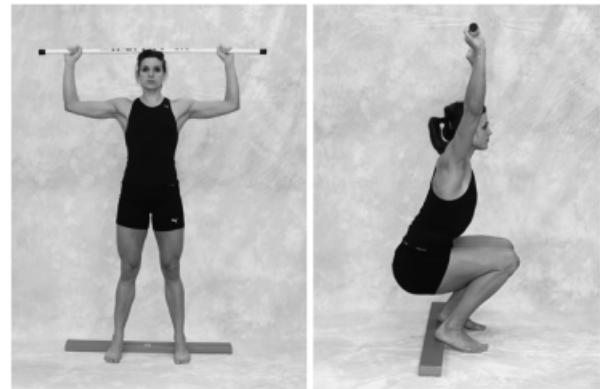


Fig. 1. Deep squat test.

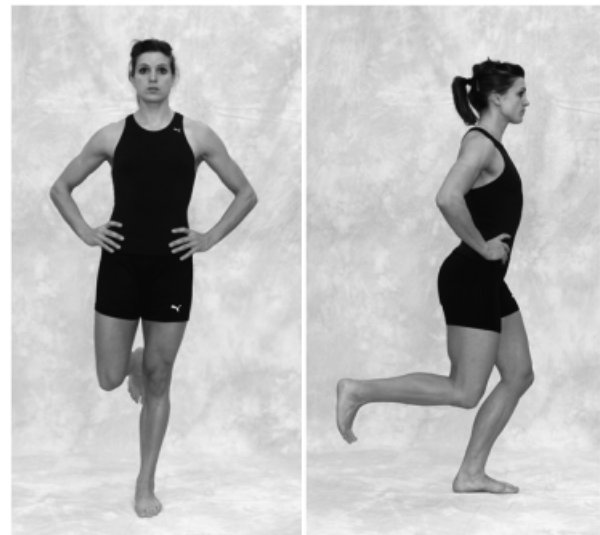


Fig. 2. One-legged squat test.

of with shoes. From clinical experience it was realized that few athletes manage to perform a deep squat barefoot with femur below the horizontal. Therefore a 2 cm board was standardized as normal performance for athletes. For the in-line lunge test (Fig. 3), active hip flexion (Fig. 4) and the push-up test (Fig. 6) more strict criteria have been developed, not allowing compensatory movements. The diagonal lift test (Fig. 7) was only tested diagonal and not ipsilateral and the test was performed on a narrower surface. The shoulder mobility test (Fig. 9) had the same criteria as the FMS but the description of

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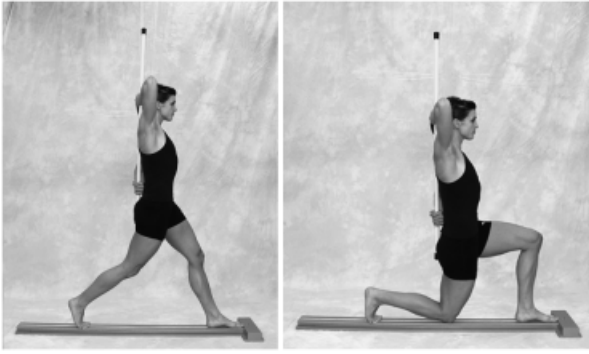


Fig. 3. In-line lunge test.



Fig. 4. Active hip flexion test.



Fig. 5. Straight leg raises test.

the starting position was standardized to prevent compensatory movements. The purpose of using the nine tests was to accomplish a test battery for fundamental movements that specifically aim to stress components like stability and



Fig. 6. Push up test.

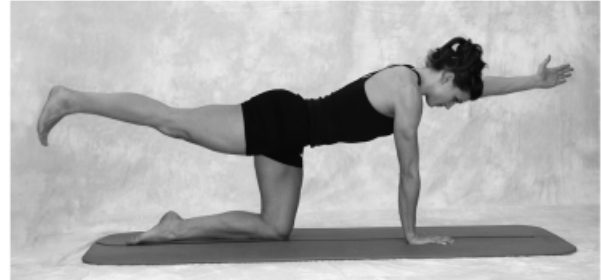
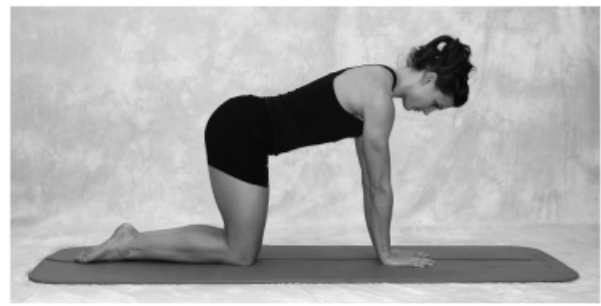


Fig. 7. Diagonal lift test.

mobility in the kinetic chain of the body. Each exercise was standardized in order to assess more mobility, stability and neuromuscular control.

For each test the athlete was instructed to move from a starting position to a final position according to a specific description. The positions and movements were graded according to a four-point scale (3-2-1-0), 3 representing “correct with no compensatory movements,” 2 “correct but with presence of compensatory movements,” 1 “not correct despite compensatory movements” and 0 if pain was present. The athlete can reach a maximum score of 27 points. All tests were performed barefoot, with tights and a sports top. Mirrors were not used. The whole test battery took approximately 30 min to accomplish.

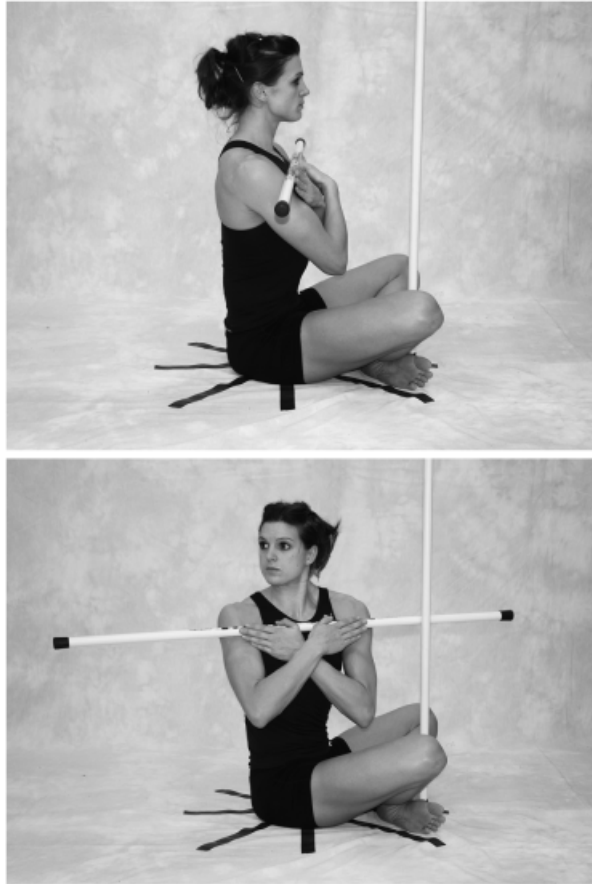


Fig. 8. Seated rotation test.



Fig. 9. Functional shoulder mobility test.

Procedure

At the test occasion each athlete was verbally informed about the test procedure by one of the authors (A. F.). The athlete entered the test room, where eight physiotherapists with scoring sheets moved freely. They were requested to blind their scores to others and communication was not allowed. One physiotherapist (P. S.) gave a standardized verbal instruction and a photo of the starting and finishing position of an optimally performed exercise was shown. During the three trials, verbal corrections was given to the athlete in order to

achieve the most optimal performance. For bilateral tests, the left extremity was tested first. The lower of the two scores for the left and right side was used for the data analysis. The maximum score achieved was recorded and used for evaluation of test performance.

Statistical analysis

Data for total and individual scores (by item and occasion) have been evaluated using descriptive statistics, SD. Intra- and inter-rater reliability was analyzed using intra-class correlation coefficient (ICC), according to Bland and Altman (1986). ICC is a relative measure, which describes the variation between cases in relation to the total variation in all observations. The greater the variation between or within raters is, the smaller the value of ICC. ICC varies between 0 (no reliability) and 1 (complete reliability, i.e. no variation within or between raters). Analysis of variance (ANOVA), with repeated measurements design was used to estimate the within-item, occasion and rater variance. An absolute measure of variation was also estimated, the measurement error (ME) which enables clinical judgment of the size of the variation within raters and test occasions. The inter-rater reliability for the total score of the test battery was estimated at the first occasion using 26 subjects, and at the second occasion using 18 subjects. Inter-rater reliability by item was estimated at the first occasion.

Systematic differences on a group level, i.e. differences between means were tested using a repeated measurement ANOVA with two factors, occasion (two levels) and testers (eight levels). Estimated differences between occasions and examiners are presented using least square (LS) means together with its 95% confidence interval (CI).

Factor analysis with varimax rotation and 0.70 levels for factor loading was used to analyze the number of underlying factors and the correlation between items, i.e. items which were associated to the same factor. Also, the Chronbach's alpha was used to estimate the internal consistency between items.

All tests were two-sided and $P < 0.05$ was regarded as statistically significant. Statistica (v 7.0, Statsoft Inc., Tulsa, Oklahoma, USA) was used for statistical calculations.

Results

Inter-rater reliability

No significant difference ($P = 0.31$) was found between test occasion 1 (LS means 18.3, 95% CI 14.9–21.7) and test occasion 2 (18.0, 14.4–21.7) in the mean total score of the test battery. The ICC was 0.80 and 0.81, respectively.

A significant difference between physiotherapists with regard to the mean total scores was found at test occasion 1 ($P < 0.001$) and was indicated at test occasion 2 ($P = 0.06$) (Table 2). *Post hoc* showed significant differences between the physiotherapists 5, 6, 7 vs 1, 4 ($P < 0.05$). The score for each physiotherapist is illustrated in Fig. 10.

Intra-rater reliability

The ICC and the ME for intra-rater reliability by physiotherapist are presented in Table 2. The mean

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Table 2. Mean total score and standard deviation (SD) by physiotherapists ($n = 8$) at test occasion 1 and test occasion 2

Physiotherapist	Test occasion 1 (mean, SD)	Test occasion 2 (mean, SD)
1	18.8 (0.6)	18.6 (0.7)
2	18.4 (0.6)	17.6 (0.6)
3	18.7 (0.6)	18.2 (0.6)
4	19.1 (0.6)	18.6 (0.7)
5	17.6 (0.6)	17.7 (0.6)
6	17.6 (0.8)	17.8 (0.6)
7	17.7 (0.7)	17.8 (0.7)
8	18.3 (0.5)	17.9 (0.7)

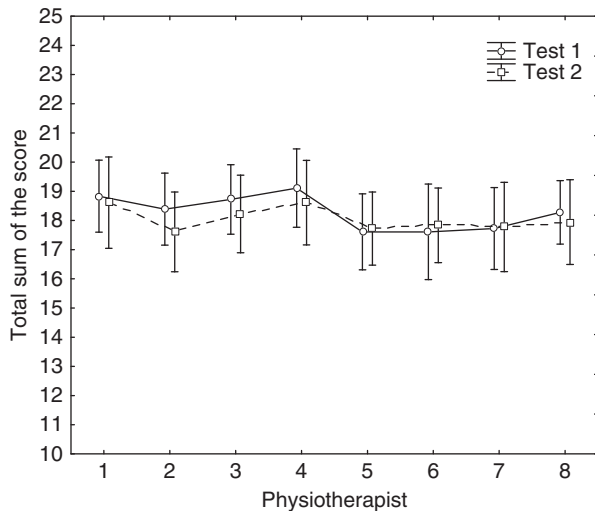


Fig. 10. Mean total score and 95% confidence intervals by physiotherapist at test occasion 1 and test occasion 2 ($n = 18$).

ICC for intra-rater reliability within the physiotherapists was 0.75 (Table 3).

The inter-rater reliability for each exercise ranged between 0.30 and 0.85 at first test occasion, (Table 4).

Internal consistency and factor analysis

A moderate inter correlation among the nine exercises was seen, 0.43. Further analysis showed that deep squat and in-line lunge test was strongly related to one factor, loadings of 0.84 and 0.73, respectively, and the items active hip flexion and straight leg raise with loadings 0.84 and 0.79, respectively, were strongly related to another factor (Table 5).

Discussion

This study reports on the inter- and intra- rater reliability of a nine-test battery for athletes, as well as for each exercise. The principal findings of this study were that the inter-rater reliability was good

Table 3. Intra-class correlation coefficient (ICC) and measurement errors by physiotherapist in total score of the test battery (physiotherapists, $n = 8$ and subjects, $n = 18$)

Physiotherapist	ICC ($n = 18$)	Measurement errors ($n = 18$)
1	0.87	2.0
2	0.77	2.4
3	0.83	2.0
4	0.77	2.6
5	0.79	2.2
6	0.45	4.2
7	0.79	2.6
8	0.75	2.4

Table 4. Mean intra-class correlation coefficient (ICC) and measurement error for the different exercises ($n = 9$), physiotherapists ($n = 8$) and tested subjects ($n = 18$)

Exercises	ICC ($n = 18$)	Measurement errors ($n = 18$)
Deep squat	0.73	0.65
One-legged squat	0.53	0.61
In-line lunge	0.74	0.64
Active hip flexion	0.81	0.72
Straight leg raises	0.64	0.84
Push up	0.63	0.67
Diagonal lift	0.30	0.93
Seated rotation	0.65	0.60
Shoulder mobility	0.85	0.52

Table 5. Factor analysis

	Factor 1	Factor 2
Deep squat	0.28	0.84*
One-legged squat	-0.27	0.67
In-line lunge	-0.14	0.73*
Active hip flexion	0.83*	0.04
Straight leg raises	0.79*	0.01
Push up	0.53	-0.00
Diagonal lift	0.30	0.06
Seated rotation	0.34	0.02
Shoulder mobility	0.21	0.07

*Intercorrelations > 0.07 are considered strong.

(0.80) and that no significant difference was seen in mean total score between test occasion 1 and occasion 2. These results indicate that the test battery as a whole is a reliable tool to screen for function of athletes in a clinical setting.

To define whether a movement is sufficient or not is a delicate dilemma because it certainly can vary for different sport-performance. Throughout the conduction of the present study it was hypothesized that a total score below 18 points (67%) according to the criteria was less sufficient. This has been strengthened by a study conducted of Kiesel et al.

(2007) aiming to investigate professional football-players scoring on FMS and the tests ability to predict injury. Their results indicate that those players scoring below 14 (67%) on the FMS were more likely to be injured than those scoring above. Even though most tests in the nine-test screening battery is based on the FMS it is not known if a high score on this test battery, meaning a more optimal performance, can predict or prevent injury.

The maximum total score for the test battery is 27 p, each exercise is assessed using a graded four-point scale. A low score indicates exercises with pain (0) or 1 point during some of the exercises. Each exercise is analyzed separately to identify functional weak links, and individual exercises are prescribed to restore a more normal function. It is important to keep in mind that the test battery does not include single joint-specific tests. When pain occurs during testing, we recommend further examination and follow-up by physician.

The results for each exercise suggests that the inter-rater reliability can be considered good, except for the one-leg squat test (0.52) and the diagonal lift test (0.30). There are several possible explanations for the low ICC values for these two exercises. The judging criteria might not have been clear enough for these more complex exercises and subsequently variation in scoring will increase. Both the one-legged squat and diagonal lift test involve several joints and several physical qualities such as trunk- and lower extremity stability, balance and coordination and are therefore more challenging to assess. The inter-rater reliability of the FMS was recently studied (Minick et al., 2010) and reported to be satisfying. In that study, the movements were video-recorded and analyzed by two experts and two novices. The authors discussed the limitation of their method in terms of lack of three-dimensional approach and found out that the lower Kappa-values in the lunge and rotator stability test are best scored by evaluating all three planes of motion. The nine-test battery is supposed to be used in a clinical setting. In our study video analysis was not used. However, the ICC was low for some of the exercises that should be analyzed in more than two planes. It can be discussed whether the grading system is sensitive enough or alterations are needed. It is too early to decide on if exercises should be removed. Future studies will evaluate the sensitivity of the nine-test battery.

The test battery can be used for screening entire teams, because a skilled physiotherapist can complete the battery in <30 min. However, different sports require specific skills and movement patterns (Sato & Mokha 2009). Therefore, this test battery could serve as a basic movement screening, which can be supplemented with other, more sport-specific tests. In addition, this test battery may have limita-

tions for overhead athletes because only one test (Fig. 9) focuses on upper limb function. Thus, regarding athletes involved in sports including intensive use of the upper limbs, additional screening is suggested from the USTA HPP.

The homogeneity of the nine-test battery can be considered satisfying, 0.43, meaning that it is sensitive to multiple dimension, because higher alpha-values indicates homogeneity. This can however be discussed, because some professionals, as a rule of thumb, require a reliability of 0.70 or higher before they will use an instrument. The following factor-analysis strengthen our explicit thought by indicating that two exercises, the in-line lunge and deep squat, were strongly related to one factor and that active hip flexion and straight leg raise were strongly related to another. The other five exercises were independently reflecting other dimensions, meaning not correlated to the same factor. One can argue that these results may indicate that only one of the exercises related to the same factor can be excluded from the test battery, however, because no validity study yet has been performed and it might be useful that one factor is screened in several dimensions it is still motivating to keep all the nine exercises in the nine-test battery.

Peate et al. (2007) indicated that a screening with a test battery, followed by individualized prescribed training, reduced injuries among firefighters by 42% compared with historical controls. This study has, however, some methodological limitations, because the methods are not tested for reliability. However identifying weak links and restoring normal function could be considered as primary prevention. If normal function, in this setting meaning a high score on the test battery, results in fewer injuries among athletes is not known. In recent studies, it has been shown that reduced neuromuscular control (Risberg et al., 2007), increased knee valgus moment (Myklebust et al., 1997; Hewett et al., 2007) and reduced core stability are risk factors for anterior cruciate ligament (ACL) injuries (Zazulak et al., 2008). Zazulak and colleagues tested prospectively 277 collegiate athletes for trunk displacement after a sudden force release in order to identify predictors of risk in athletes who sustained knee injury. They concluded that factors related to core stability predicted risk of athletic knee, ligament and ACL injuries with high sensitivity and moderate specificity in female, but not in male athletes. There is although another study that debates the correlation between good core stability and increased performance (Okada et al., 2010). In addition, it has been suggested that a history of knee injury is a risk factor for a subsequent knee injury (Hägglund et al., 2006; Steffen et al., 2008) or ACL injury (Waldén et al., 2006; Faude et al., 2006). One theory could be that normal function is not restored

after injury and adequate rehabilitation has not been completed. However, there are no clinical trials using functional screening tests and prescribing targeted exercise programs in athletes to test this hypothesis.

Hibbs et al. (2008) pointed out the importance of finding a precise balance between stability and mobility and that the role of sensory-motor control is more important than the role of strength or endurance of the trunk muscles when testing athletes for performance. The test battery presented in the present study partly aims to detect such imbalances. A further aim of the test battery is to assess core stability as well as increased joint range of motion, muscle flexibility and joint stability, which is in accordance with Tse et al. (2005) and Hibbs et al. (2008). It would be of great importance to create evaluation methods or test batteries that could be used to assess such imbalances.

In this study male elite soccer players were used as a model. Therefore we do not know if the results can be generalized to both sexes, other age groups or other sports. However, in a previous study (McCurdy et al., 2004), conducted to determine the reliability of the one- and three-repetition maximum strength test, high reliability was found independent of gender or training experience. The literature is sparse regarding reliability and functional tests but both Minick et al. (2010) and our study showed good inter-rater reliability.

One can argue that more years of clinical experience or holding advanced or specialist certification contribute to improved assessment of patients. There are no previous studies regarding this specific topic. However, Whitman et al. (2004) found that increased experience did not result in an improvement in patient's disability associated with low back pain treated with standardized physical therapy management program. In our study, four of the physiotherapists could be regarded as experienced and four as less experienced and familiar with the testing procedure. In the result section, at test occasion 1, it can be seen that it was a significant difference in the mean total score between physiotherapists as indicated ($P = 0.06$) at test occasion 2. Further, the statistical power was high although the absolute difference was small. As shown in the results, the first group scored the athletes on average 1 point higher for the whole test battery compared with the latter, which probably is of less clinical importance.

No familiarization session for the athlete was allowed before the three trials were performed.

Ploutz-Snyder and Giamis (2001) stated that the reliability for strength tests increases with two to five testing sessions. The low inter-examiner reliability for the more complex exercises in our study, such as the one-legged squat test and diagonal lift test, might have been higher if the athletes had been introduced to an adaptation session before the testing. However, corrective instructions were given to the athlete between each trial. In addition, the best of the three trials was recorded for calculation.

A methodological limitation in the present study is the risk of contamination. However, none of the athletes had been involved in prior tests or treatment from any of the included physiotherapists. Further, we consider the risk that the physiotherapist remembered the score to be low because 26 athletes were screened the first day and 18 of the 26 athletes were screened 7 days later.

This functional movement test battery, used on male elite soccer players, showed good inter- and intra-rater reliability. The test battery is easy to use for familiarized professionals, requires minimal equipment and is not time consuming. However, further studies are needed to confirm these results, as well as to examine the validity or responsiveness of the test battery in injury prevention, rehabilitation and performance enhancement.

Perspectives

Assessing quality of movement patterns is challenging and because a precise balance between stability and mobility has been suggested to possibly prevent injuries and enhance sport performance, sensitive tools and appropriate methods is needed. It is important that clinical test batteries, used in clinical settings and aiming to detect mal alignments are reliable as well as validated. This test battery showed good inter- and intra-reliability. In the present study no test for validity was performed. Future studies will address validity and responsiveness of the test battery.

Key words: clinical test, function, inter-rater, intra-rater, movement pattern, performance.

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