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Methodological Item Analysis of the Functional Movement Screen

Methodologische Itemanalyse des Functional Movement Screen

REVIEW

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Summary

- **Aim:** The FMS is widely used to assess motor control and to estimate injury risk. However, the proceeding injury-risk-validation has shown contrary evidences. Unlike promising pilot-studies, current studies identified a low diagnostic accuracy of the FMS cut-off score. A potential explanation for this might be the inhomogeneous factor structure which raises questions about the sum score application.
- **Methods:** 445 professional and lay sportsmen were analyzed in order to determine the item difficulty and the item discrimination of the FMS tasks. The item difficulty index described by Lienert and Raatz as well as item discrimination index by Ary were used to evaluate item difficulty and item usefulness of the FMS screening battery.
- **Results:** The item analysis describes the FMS as a difficult screening battery (Index 37.7). Generally, the items range from easy to very difficult. Within the group of Olympic athletes (n=290), item difficulty of the screening battery is described as moderate (Index 45). Rotary Stability represents the most difficult item in both groups. In contrast to more complex movement tasks, simple tasks are highly associated with the FMS sum score.
- **Discussion:** The practical value of our examination is the possible classification of the FMS into two categories. Category one is screening for local musculoskeletal flexibility which is to a certain extend a necessary prerequisite for category two - the evaluation of basic motor performance. In order to estimate injury-risk, the gathered information by the FMS seems to be not specific enough to make serious injury-risk-prognosis.

Zusammenfassung

- **Problem:** Der FMS wird breitflächig eingesetzt, um die Bewegungskoordination zu beurteilen und das Risiko einer Verletzung einzuschätzen, wenn auch die Verletzungsrisiko-Validierung gegensätzliche Beweise zeigt. Im Gegensatz zu vielversprechenden Pilotstudien liefern derzeitige Studien Hinweise auf eine geringe diagnostische Genauigkeit des Cut-off Scores für ein erhöhtes Verletzungsrisiko. Ursache hierfür könnte die Faktorstruktur sein, die inhomogen ist und damit die Anwendbarkeit der Gesamtsumme in Frage stellt.
- **Methode:** Für die Aufgabenschwierigkeitsanalyse wurden Datensätze von 445 Athleten und Fitnesssportlern analysiert und nach dem Aufgabenschwierigkeitsindex von Lienert und Raatz sowie des Item Diskrimanz Index nach Ary evaluiert.
- **Ergebnisse:** Die Itemanalyse zeigt, dass die Screening-Batterie schwierig ist (Index 37.7). Insgesamt verteilten sich die Testitems des FMS von leicht über moderat bis sehr schwer. Bei den professionellen Sportlern (n=290) verändert sich der Schwierigkeitslevel zu moderat (Index 45). Jedoch zeigt sich in beiden Gruppen Rotary Stability als die Aufgabe mit der höchsten Schwierigkeit. Einfache Bewegungsaufgaben wie Shoulder Mobility (r=0.6) oder Active Straight Leg Raise (r=0.7) korrelieren deutlich mit dem Gesamtscore, während komplexere Teilaufgaben wie Hurdle Step (r=0.2), Trunk Stability Push Up (r=0.2) and Rotary Stability (r=0.15) nur schwach mit der Gesamtpunktzahl in Beziehung stehen.
- **Diskussion:** Nach unseren Erkenntnissen sollte der FMS in zwei Kategorien eingeteilt werden: Zum einen die lokale muskuloskeletale Flexibilität als Voraussetzung für die Evaluation der motorischen Leistung zum anderen. Trotzdem erscheint die FMS-Gesamtpunktzahl nicht spezifisch genug für eine Verletzungsprognose.

KEY WORDS:
FMS Sum Score, Injury Risk, Injury Prevention, Pre-Participation Screening, Item Analysis

SCHLÜSSELWÖRTER:
FMS, Aufgabenschwierigkeit, Bewegungsanalyse, Funktionsdiagnostik, Itemanalyse

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Introduction

The ultimate goal of sport science is the reflective and efficient implementation of research findings in order to enhance health and performance in real -sport settings. However, the quality of information along with certain circumstances can influence the practical application of scientific findings. The following circumstances like limited time, equipment or different quality in the coaching staff affect the practical outcome (3). Therefore, on field we have to look for a productive balance between efficacy and efficiency in designing new methods or technologies. Movement screens are intended to vividly ascertain injury risk factors like muscular imbalances, in order to determine improvement and to educate athletes (5). For this purpose in the field of functional training the Functional Movement Screen has ›

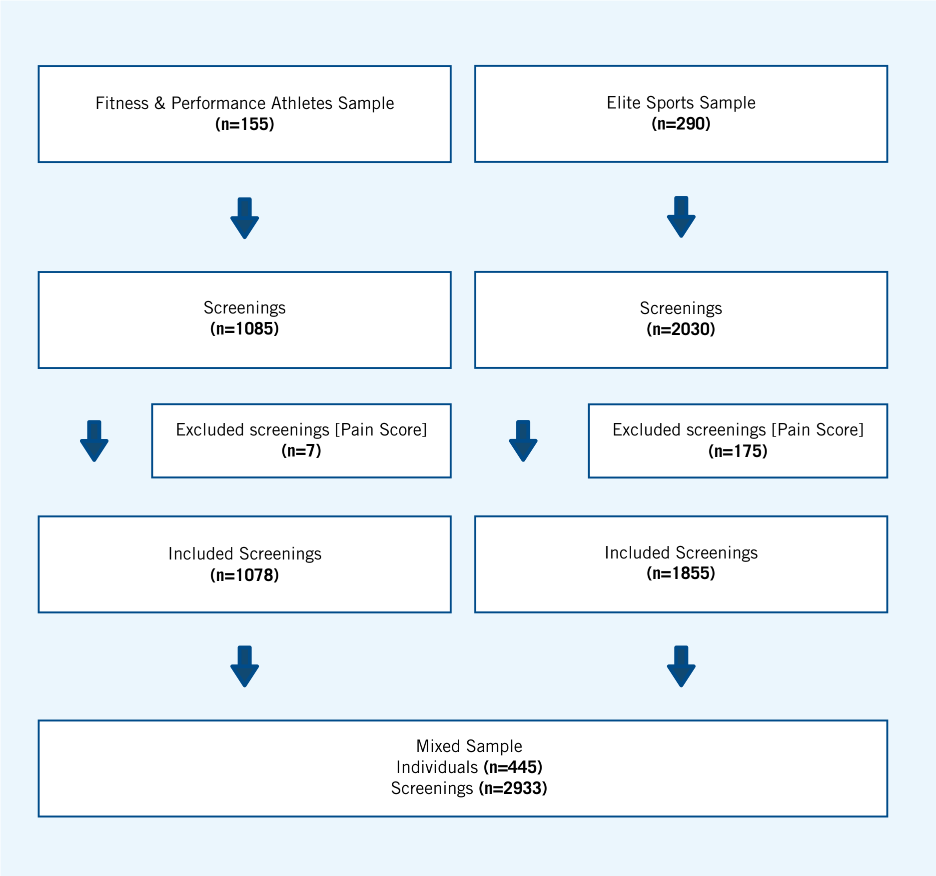

Figure 1
Flowchart of data processing.

been developed to screen musculoskeletal deficits (4) in various settings without locomotion. The FMS grounds on the developer´s assumption that strength, flexibility, mobility and postural stability are prerequisites for musculoskeletal health and optimal athletic performance (9). Furthermore, the FMS detects functional movement symmetry. Overall, the screening tool consists of a series of unloaded movement tasks assessing functional ankle, knee, hip and shoulder mobility, external and internal rotation as well as postural stability and ab/adduction of the shoulder joints (9). Today, the FMS is widely used to assess general motor control and movement related pain. For instance, McCall´s survey of 44 professional soccer teams has shown that 66 % of the evaluated clubs use the FMS in order to detect the risk of non-contact injuries (23). However, the proceeding criterion-based injury-risk-validation has shown contrary evidences. Unto promising pilot-studies (6, 15) more sophisticated examinations identified a low diagnostic accuracy of the FMS cut-off score of ≤14 in order to predict injury-risk (16, 17). Though, based on this evidence it is not serious scientific practice drawing the conclusion that the FMS cut-off score is appropriate to estimate injury-risk. In fact, these results yield a fundamental issue on the desk. This fundamental issue has a strong methodological background - the item analysis. The aim of this analysis is to shed light on the interplay and the level of difficulty of the items (1).

Aim of this Investigation

After reviewing the literature, a methodological examination of the FMS items was not prepared (18). Instead of conducting another injury-risk-study, this item analysis seems to be more beneficial for the further development of the Functional Movement Screen, because, from a methodological standpoint, the application of the FMS sum score suggests that all items of the FMS and scores are homogeneous and internally consistent. Furthermore, the usefulness of the different tasks of a screening battery are also of high value. For this purpose the usefulness of an item within a screening battery should correlate at least 0.25 with the total score. If not they are not measuring the same thing and hence they are not contributing to the measurement of the same construct (1).

However, the underlying factor structure is not unitary. This is the result of two explanatory factor analysis. Based on these results, the FMS might have two underlying constructs (14, 20). Originally, the factor analysis was developed for parametric data, while the FMS provides ordinal data based on a four-point ranking system (30). Therefore, we feel uneasy about treating non-parametric data as parametric data due to a clear understanding that the issue is neglected in daily routines like the calculation of grades at school. In traditional test theory, the first step of item analysis are to determine the task´s difficulty and the item discrimination index. The goal of this approach is twofold. First: Increasing reliability and validity by revising or reducing test items. Second: Proving the scoring assignment in order to enhance reliability and higher accuracy of norm data. In psychology, item difficulty is defined as the percentage amount of right answers in a given population (21). In our case, we adapt this definition to the correct performance of each movement pattern (score 3). In this analysis we are proving the hypothesis that the FMS items are of varying difficulties. Based on our practical experience, we expect that rotary stability is the most difficult item.

Material and Methods

Subjects

The sample size consisted of 155 healthy and active recreational sportsmen (fitness athletes) with various sports histories (n=110) and semi-professional athletes (performance athletes) from the areas of football, swimming and track and field (n=45). 37 females, 22.5±3 yr and 118 males, 23.6±3.2 yr, volunteered to participate in this investigation and underwent written informed consent prior to their participation. Ethical permission was provided for the study by the local ethical review board. In order to increase the methodological quality, we also used the published data of the elite sport sample (n=290) of Li and colleagues (20).

Procedure

All 155 participants underwent the screening at the research lab. The subjects were tested between June 2012 and December

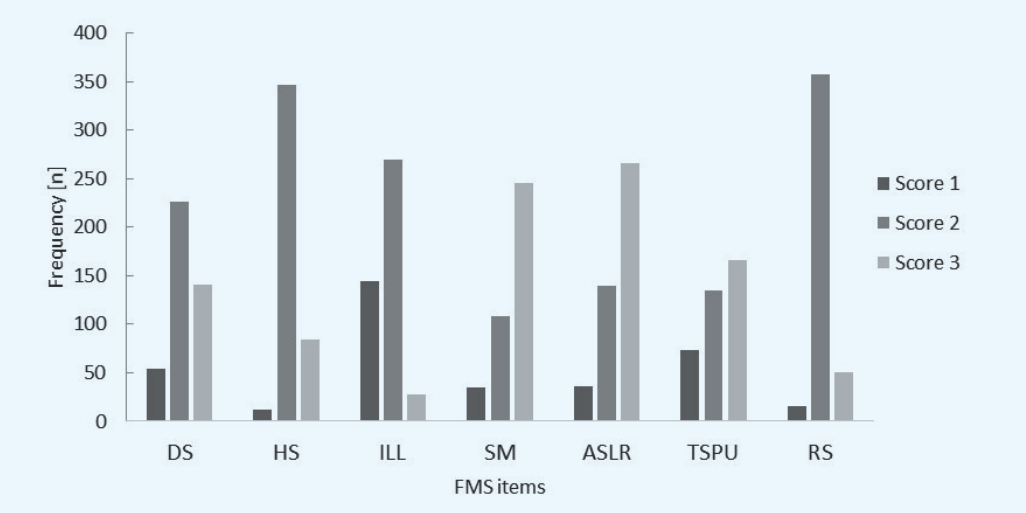

Figure 2

Test results for items of the Functional Movement Screen: deep squat (DS), hurdle step (HS), inline lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability pushup (TSPU) and rotary stability (RS) (n=445). Qualitative score: score 3 perfect performance, score 2 with compensatory movements patterns, score 1 movement not completed.

2014. Furthermore, the subjects were asked questions concerning age, exercise history and prior injuries. The data of the elite sport sample by Li (20) was combined with our data for item difficulty analysis. General procedures are presented in the flowchart (Fig. 1.).

Functional Movement Screen: The FMS consists of a number of tests assessing hip flexion, external and internal rotation as well as core stability and ab/adduction of the shoulder joints. The sub-tests include the following: deep squat, hurdle step, in-line lunge, shoulder mobility test, active straight leg raise, trunk stability push-up and a rotary stability test. All subtests are performed at least three times, while the best trial is scored. The total FMS score is the summation of all seven sub-test scores, resulting in a maximum of possible 21 points. A four-point ranking system is used to evaluate the movement quality, in which a score of „3“ describes the correct performance of the movement pattern, „2“ indicates that the subject needs compensatory movements to solve the sub-test and a score of „1“ is indicated when the individual is not able to perform the movement pattern at all. In some cases, subjects feel pain while performing a subtest, in which case a score of „0“ is given. Five of the seven FMS items (hurdle step, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability test) are performed independently on the right and left sides of the body. The lowest score of the two sides contributes towards the final item score. For example, an in-line lunge score of 3 on the left side and 2 on the right side is rated as a score of 2 for the in-line lunge sub-test (9).

Statistical Analysis

The aim of task analysis is to test whether the tasks are appropriate for the given population. Per definition, item difficulty of a task equals the percentage amount of correct movement patterns. In order to determine FMS item difficulty, we used the frequency as well as the item difficulty index described by Lienert and Raatz (21).

$$P = 100 * NR/N$$

P= Item difficulty index
NR= Amount of correct movement patterns (score 3)
N= Number of subjects

We set up 5 levels of item difficulty to differentiate between each item. 0-19 percent is classified as very difficult, 20-39 percent as difficult, 40-59 percent as moderate, 60-79 percent as simple and 80-100 percent as very simple. In order to reduce the impact of inconsistency, the heuristic “pain criterion” was controlled by excluding all pain scores – score 0.6 from the fitness and performance sport sample and 175 screenings from the elite sport sample (20).

Spearman rank correlation coefficient was used to determine possible interrelations between items. Spearman correlation coefficient is described as trivial (0.0-0.1), low (0.1-0.3), moderate (0.3-0.5), high (0.5-0.7), very high (0.7-0.9) or practically perfect ranging from 0.9 to 1.0 (8). The level of statistical significance was set at 0.05. Item difficulty was analyzed with Excel 2010 (Microsoft, Redmond, WA). Statistical analysis were completed by using SPSS Version 22 (IBM Corporation, Armonk, USA).

Results

Mixed sample item analysis: Frequencies of the FMS items are presented in Figure 2.

Fitness and performance sport sample: Item difficulty analysis generates two categories: one group of very difficult and one group of moderate items. Deep squat, hurdle step, inline-lunge and rotary-stability are shaping the category of very difficult items. Active straight leg raise is rated as difficult item, whereas shoulder mobility as well as trunk stability push-up are allocated to the category of moderate item difficulty. Hurdle step and rotary stability were ranked as the most difficult item with an index of 3.9. Shoulder mobility is the simplest item with an index of 53. The average item difficulty of the FMS screening battery is ranked as difficult (23.7). Correlation analysis illustrated a moderate relationship between the items active straight leg raise and shoulder mobility (r=0.4; n=154). Cronbach´s alpha amounted to 0.15 for the scores of 7 tasks.

Elite sport sample: We identified two simple (SM, ASLR), three moderate (DS, ILL, TSPU), one difficult (HS) and one very difficult item (RS). On average, the item difficulty analysis rated the FMS screening battery as moderate (index 44.9).

Mixed Sample: Overall, score 1 was given 369 times, score 2 was given 1584 times and score 3 was given 980 times. Score 2 is the mode for the items DS, HS, ILL and RS, whereas score 3 is mode for SM, ASLR and TSPU. The combination of both samples carved out: two very difficult items (HS & RS), two difficult items (DS & ILL), two moderately difficult items (ASLR & TSPU) and one simple item (SM). Altogether, item difficulty analysis ranked the FMS screening battery on a difficult level (Index 37.7). Detailed information is presented in Figure 2 and 3.

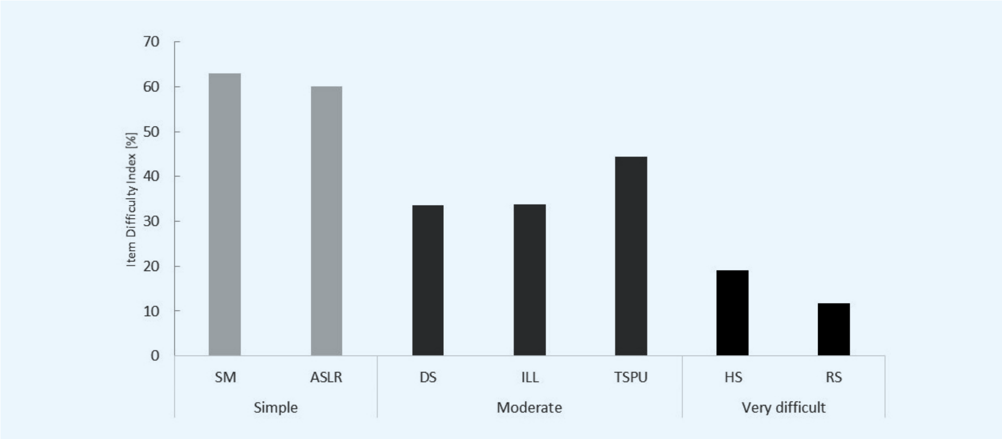

Figure 3

Item analysis of the levels of item difficulty for the Functional Movement Screen (n=445) according to 3 categories of item difficulty: - simple - shoulder mobility (SM), active straight leg raise (ASLR), - moderate - deep squat (DS), inline lunge (ILL), trunk stability push-up (TSPU), - difficult - hurdle step (HS), rotary stability (RS).

Item Discrimination Index

Simple movement tasks like shoulder mobility (r=0.6; n=154) as well as active straight leg raise are highly associated with the FMS sum score (r=0.7; n=154). Whereas, more complex movement tasks like hurdle step (r=0.2), trunk stability push up (r=0.2) and rotary stability (r=0.15) do not correlate with the total score and they are below the item discrimination index criterion.

Discussion

"The hallmark of science is a certain scepticism even towards one´s most cherished theories. Blind commitment to a theory is not an intellectual virtue: it is intellectual crime", the father of the methodology of scientific research programmes Imre Lakatos points out (19). These challenging words nourished the appetite of answering the following question: What is the Functional Movement Screen actually screening for? Overall, movement specialists receive a general impression of an individual's postural stability and functional mobility. They are guided by the following objectives: differences in local flexibility, movement related pain and symmetry in movement patterns.

However, the application to injury prediction or motor performance requires knowledge about the underlying construct or phenomenon being subject to measurement. Nowadays, we can quantify almost anything. Nevertheless, if we cannot assess the phenomenon properly, the numbers will be deficient and in the worst case, they will leave us clueless (27). In order to design highly individual training programmes or to educate athletes, valid information is necessary to maintain credibility.

In order to investigate this fundamental question, two independent research groups prepared an explanatory factor analysis (EFA). Both groups concluded that the FMS does not ground on a unitary construct. This falsification provides evidence against the application of the FMS sum score (14, 20). Furthermore, the results can be used as an explanation for the controversy results of the FMS sum score in attempts of predicting the occurrence of injuries (6, 13, 17, 25, 32, 33).

The falsification of the predictive body of the FMS could lead to the position that we are done researching. Nonetheless, using Karl Popper's falsification as an argument against critical discussion and better experiments might not be in his favour. We prefer to rely on his words: *"There is nothing more rational than the method of critical discussion, which is the method of science."* A critical discussion stems from a sound understanding of the body of evidence, good questions and constructiveness.

What is a good question? We believe that both EFAs helped shedding light onto the fundamentals of the Functional Movement Screen. From a methodological point of view, investigating the underlying constructs represents the right and most productive path. If Kazman's and Li's research teams' analysis are correct, the heterogeneous structure of the FMS test battery means that the FMS cut-off score is not valid for predicting injury-risk. Contrary to both investigations, we stated our methodological concerns about the application of an explanatory factor analysis (EFA) for ordinal data. EFA requires normally distributed data as well as a sound understanding of the statistical method (10). Achieving normally distributed data appears rather problematic on a 4-point ordinal scale. Furthermore, Lienert and Raatz, states that *"a high variance in item difficulty exacerbates the interpretation of factor structure"* (21). We hypothesized and identified different levels of difficulty as well as an asymptotic distribution within both samples. Score 2 and score 3 were the most indicated scores. Altogether, 2564 of 2933 (87 percent) illustrate the skewed distribution.

Item Analysis in Fitness and Performance Sports

In our sample of recreational and semi-professional sportsmen, we found three levels of item difficulty (four very difficult, one difficult and two moderate difficult items), which led to a difficult test battery.

Thus, this may lead to the assumption that the FMS test battery is too difficult for a fitness population or that the general motor control of our population might be too low. Obviously, all items seem to be not so difficult. But practical routines and our results have shown the opposite. Aside from empirical evidence the items hurdle step and rotary stability are not so common like deep squat or trunk stability push up and hence might be more affected concerning habituation effects.

Within the scope of the very difficult items, there were no movement patterns, which were not related to each other, for instance deep squat and inline-lunge (r=0.1). This is in-line with the data of the elite sport sample by Li and colleagues (r=0.2) (20). Perhaps due to the fact that each item screens different qualities. The overhead character of the deep squat item is close to the Olympic weightlifting exercise snatch and needs a certain amount of symmetric mobility in the shoulder joints and hips in order to facilitate the spine in a locked neutral posture. In contrast to a common deep squat the overhead posture shifts the center of gravity which leads to different motor activity patterns (24). In addition this task shifts the focus towards the nature of the deep fasciae of the back. In detail, the interplay of the posterior layer of the thoracolumbar fascia, serrati-posterior fascia, anterior layer of the thoracolumbar fascia and epimysial fasciae of the erector spinae can be considered as a structural feature which might be a prerequisite for functional flexibility (28). Whereas, the item inline lunge screens for asymmetric motor performance with a focus on knee joint stability of the knee and core stability. This brief content and correlation analysis showed that both items offer different insights and should not be eliminated from the original screening battery.

In the category of moderately difficult items, shoulder mobility and active straight leg raise are significantly related to each other (r=0.4). Clearly, performing both movement tasks appears to be rather simple. In contrast to our observation, the relationship in the elite sport sample was quite low. However, we would like to point out that Li's correlation analysis was constrained by a high incidence of pain (n=55). Thus, we ought to treat this evidence cautiously. Shoulder mobility and active straight leg raise are highly associated to the FMS sum score (r=0.6 and r=0.7, respectively). In comparison to the more complex items it is easier to achieve a high score in these tasks, because they are more dependent of joint structure and local flexibility of the tissues than motor control. Based on this body of evidence it might be helpful to develop two categories. The first category is a local musculoskeletal flexibility screening (SM and ASLR) as prerequisite for complex musculoskeletal mobility and motor control. In addition, it seems to be interesting to integrate strength in active range of motion (ROM) measurements, because isolated ROM without force development is not common in daily or sporting routines (11). Furthermore, complex items like hurdle step are rated below the discrimination index. This result suggests that these tasks or the scoring procedure should be reconsidered, ideally with a stronger focus on content and construct validity.

Summarizing, 2 of 3 moderate difficult items have a higher impact on the FMS score than the 5 remaining ones in our fitness and performance sport sample. This is another indicator speaking against the unreflective application of the sum score for the purpose of injury prediction. Furthermore, debates about injury causation highlights that internal and external risk factors are necessary in order to understand injury mechanisms. In this regard the information of the FMS provides an overview concerning joint and postural stability at very slow movement speed and low impact situation. However, this is not the situation in which injuries occur. Injuries occur mostly in a fatigued state with reduced neuromuscular control, a chronic negative musculoskeletal load balance or contact with opponents. Therefore, the generated evidence by the FMS might be beneficial in order to focus on balanced and symmetric movement in conditioning practice. However, the usefulness of injury-risk-prognosis is not supported by scientific evidence.

Mixed Sample Item Analysis

At the outset it is important to note that the FMS helps identifying movement related pain in 175 of 2030 screenings (8.6 percent) within the elite sport sample and the mixed sample, in 181 of 3115 screenings (5.8 percent). This is practical evidence for the application of the pain score 0, especially when we consider that pain is assumed to be a deciding factor for overuse injuries (2). In contrast to practical considerations, we have to use a subjective pain scale to collect more detailed data for statistical analysis. In addition, this scale offers a simple and economic approach to monitor progressions in huge cohorts. Due to practical reasons, we recognize benefits in the implementation of the pain score in order to enhance athletes' awareness of specific problems.

In contrast to the mode analysis, item difficulty analysis categorizes the FMS items into four groups as opposed to two. There are two very difficult (RS and HS), two difficult (DS and ILL), two moderate (ASLR and TSPU) and one simple item (SM) that characterise the FMS of our mixed sample analysis. In addition to our fitness and performance sample, the FMS items analysis ranked the FMS screening battery to a difficult level (index 37.7) as well. However, we have to consider the twofold impact of the elite sport sample (index 44.9 – moderate). Moreover, our dataset is constrained by the gender effect.

Nonetheless, this item analysis has shown that rotary stability is the most difficult item of the screening battery (index 11.8), which in turn supports our hypothesis. It might be caused by the fact that trunk control is not emphasised enough in practice, or the participants are not as familiar with such a kind of exercise. This reflection raises possible questions for future research.

However, the impact of the scaling system should be investigated as possible constraint to our results. In many cases, practical application leads to the assumption that the scoring system is not precise enough to determine possible progressions of movement quality. This assumption is based on the fact that a broad range of movement patterns can be evaluated within the same score (19). Another constraint to our results is the twofold impact of the Olympic sport sample (n=290 vs. n=155). Treating this data as fact could lead to wrong decisions in research as well as in practice (32). Future investigations should focus on the development of the scoring system. For instance, the differentiation between concentric and eccentric muscle activities could provide meaningful insights, or different loads could help differentiating between scores.

Our goal was to provide a different methodological perspective on the fundamental item analysis of the FMS. History has illustrated that statistical tools are shaping objects and vice versa. Knowledge about this can fundamentally change research practice (12). There is no superior statistical tool. We can only use appropriate tools for distinct questions. For Tukey, "explanatory data analysis is detective work" (29). Our inspection proved that treating the results of EFA as a fact is problematic. The skewed distribution of the FMS indicates that EFA is the erroneous method for non-parametric data from a methodological point of view. A possible reason might be the ordinal character of the FMS scale. To sum up, distinguishing the right tools within the statistical toolbox requires sound methodological knowledge in attempts of producing right answers to right questions.

Progression is a product of refining theories explaining situations in which they have failed previously (7). Without continuing the examination of failure, we can neither advance a theory, nor technologies for athletes. For this reason, we are considering that an underlying theory could constitute a valuable asset for further development of the FMS scoring system. Physical stress theory will likely offer meaningful scientific evidence for the field of tissue adaptation and injury prevention (26). Magill's groundbreaking work might be relevant when assessing motor performance with the FMS (22). The successful implementation of right information is a prerequisite for gaining credibility in each profession.

Conclusion

To date, the FMS offers general information in reference to postural stability, functional mobility and asymmetries at an individual movement speed within the scope of the bodyweight. The practical value of our examination is the possible classification of the FMS into two categories. Category one is › screening for local motor limitations based on a local musculoskeletal assessment which is to a certain extent a necessary prerequisite for category two - the evaluation of basic motor performance. In order to estimate injury-risk, the gathered information by the FMS seems to be not specific enough to make a serious injury-risk-prognosis.

Conflict of Interest

The authors have no conflict of interest.

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