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Short Communication

Valid Tests to Create an Assessment for Screening for Risk Factors of Lower Extremity Injuries in Team Ball Sports

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Abstract

Background: Injuries are not only a personal disadvantage for athletes, but they can also determine a team's sporting and economic success. Many championship teams have a low number of injuries to complain about. Therefore, strategies to reduce this rate should be given more importance in performance-oriented team ball sports such as basketball, soccer and handball.

Objective: To create an assessment with scientifically valid tests for the screening of risk factors due to injuries to the lower extremities and to check it for its interrater reliability and feasibility.

Design: Pilot study with quantitative measurement methods in a one-group design.

Setting: 8 athletes (4 women & 4 men) from the top two game classes of basketball, football, and handball as well as 3 raters from the field of sports physiotherapy and sports science.

Methods: First a systematic literature search was carried out and the determined methods were evaluated and analyzed. A test battery was then formed from this, which consisted of a questionnaire on avoidance of movement behavior and nine test methods from the areas of speed, coordination, and strength. After the implementation, their interrater reliability was also determined.

Results: The test battery showed a very good feasibility. Your interrater reliability ICC (2,3) is 0.997 and can be classified as excellent. The Modified Star Excursion Balance Test of the left anterior range achieved the lowest value (ICC (2,3) = 0.989) and the highest was achieved by the Tampa Scale of Kinesiophobia, the Vestibular Balance Test Side to Side or Up and Down, Single Leg Rise Test on the left and the Side Plank Leg Raise Test on both sides (ICC (2,3) = 1.000).

Summary: The evaluations of the individual procedures and the entire test battery are to be assessed as excellent, considering the confidence interval of 95%. The feasibility is to be assessed as very good.

Keywords: Injury; Lower extremity; Prevention; Testing; Reliability; Feasibility

Introduction

Injuries not only represent personal damage to the athletes but can also determine the sporting success of those affected and their team. Ultimately, this can also mean an economic loss for the respective club or other stakeholders. Injuries have a detrimental effect on the sporting success of teams and individuals [1]. "Seven of the eight championship teams in the first two men's leagues we analyzed in basketball, ice hockey, football and handball had below-average downtime. This impressively shows that maintaining health

and-in the event of an injury or illness-its complete recovery should be a central motivation for all those involved in performance-oriented sports" [2, 3] For example, knee injuries have the greatest impact on the careers of affected athletes and their rehabilitation usually takes the longest [4, 5]. From the above, it can now be concluded that there is likely to be a great need for effective injury prevention measures in the three team ball sports of basketball, football, and handball. Therefore, an attempt is made to develop a valid test battery [6] that objectively shows the risk factors [7] that can lead to lower extremity injuries in these sports. These three will be examined during this pilot study because there is already a large amount of data [8], and they have relatively similar movement patterns. These are the so-called landing, cutting and pivoting maneuvers [9] in which injuries occur more frequently [10].

In practice, it has repeatedly been shown that the clubs are willing to prevent accidents, but they want to invest as little time and money as possible. This test battery should therefore be easy to use, cost-effective and easy to integrate into everyday training. Such a benefit examination would also provide a current health status, as outlined in the "IOC Consensus Statement on Periodic Health Evaluation of Elite Athletes in 2009" [11]. However, this would require corresponding follow-up examinations to keep it up to date. The aim of the present study is therefore to identify and, if necessary, use scientifically valid tests for screening risk factors due to injuries to the lower extremities. Those who turn out to be suitable should be brought together for a joint assessment, which can be carried out in a physically rested state. Finally, the test battery is also checked by various observers for its interrater reliability.

Methods

The design of a pilot study is chosen based on the research question of which valid tests are available to create an assessment for screening risk factors for injuries. Since the training scope can be quite different, only athletes from the top two leagues are selected for the study. This is intended to ensure a certain degree of homogeneity regarding the competitive sport-oriented practices of the respective sports. In summary, the methodology corresponds to a pilot study with quantitative measurement methods in a one-group design to investigate the feasibility, validity, and reliability of a newly designed test battery specifically for athletes from the team ball sports of basketball, football, and handball. To filter out valid tests, a systematic literature search was carried out. The literature sources used for the systematic search were the scientific online databases PubMed, the search engine Google Scholar, and articles from the source lists of existing studies. Another aspect was that the reliability of these tests should also be checked by different raters. The Intraclass Correlation Coefficient (ICC) will be used for this assessment. The ICC estimates the reliability of the judgments of any number of raters as expected [12]. In order to make it easier to organize, the raters will evaluate the assessments via video analysis.

Statistically, every athlete in the sports mentioned suffered 2.41 injuries per season. The athletes were out for an average of between 15-27 days per injury and each team had an average of between 8-14 injuries per season. This meant a total player absence time of 229-696 days per team and playing time, and each injured player missed approximately 12.66 games per season. The distribution of injuries between training and competitive games was 56.7% vs. 43.3%. The most injured areas of the body were the thigh, knee, and ankle. It was also shown that with a higher density of games or increased exposure to competition, the incidence of injuries was significantly higher [8]. Other authors also came to very similar results [13-17]. In 53.03% of cases, the mechanism of injury arose from direct force on the affected part of the body (direct contact injury). 25% occurred due to external force, which indirectly triggered the event (indirect contact injury). However, only 27.4% of injuries were caused by one's own or an opponent's foul play. The remaining 21.97% of the injuries occurred entirely without external force (non-contact injuries). So around half of all injuries were due to excessive stress or intrinsic factors [18-20]. The following movement patterns most often led to injuries to the lower extremities (Table 1) [2].

Table 1: Movement patterns preceding the injuries [2].

BASKETBALL	FUSSBALL	HANDBALL
Landing after throw/ block (37,9 %)	Running/Sprints (44,4 %)	Landing after throw/ block (29,9 %)
Running/Sprints (31,7 %)	Stops/ Change of direction (12,7 %)	Running/Sprints (29,3 %)
Standing position (8,8 %)	Landing after header (11,1 %)	Stops/Change of direction (17,5 %)
Stops/ Change of direction (8,7 %)	Standing position (4,2 %)	Standing Position (9,0 %)

As shown in (Figure 1), injuries were typically caused by various factors that could trigger such an event. Nevertheless, it was very likely that tolerance to occurring events was lower when multiple risk factors were present or some of them were more pronounced [7]. A noticeable increase in competition injuries was observed at the start of the season and after the winter break [21]. The requirement profiles were, on the one hand, the psychological willingness to move. Fear of pain or renewed injury influences self-confidence or ability to move. The Tampa Scale of Kinesiophobia (TSK) has previously been used for psychological assessment after ACL injuries [22]. Experience from previous test series had also shown that athletes achieved very high scores on this questionnaire even without a previous injury [23]. Specialists therefore recommended that this assessment be performed in addition to sports motor testing procedures. On the other hand, plays speed an important role in many sports. It is important not

only in sprint disciplines, but also in ball sports (anticipation, multi-directional sprints, jumps, shots or throws). Most often, speed can be observed in a combined form with endurance, coordination and/or strength. Basically, it's about perceiving something, decision making, reacting, and moving as quickly as possible [24].

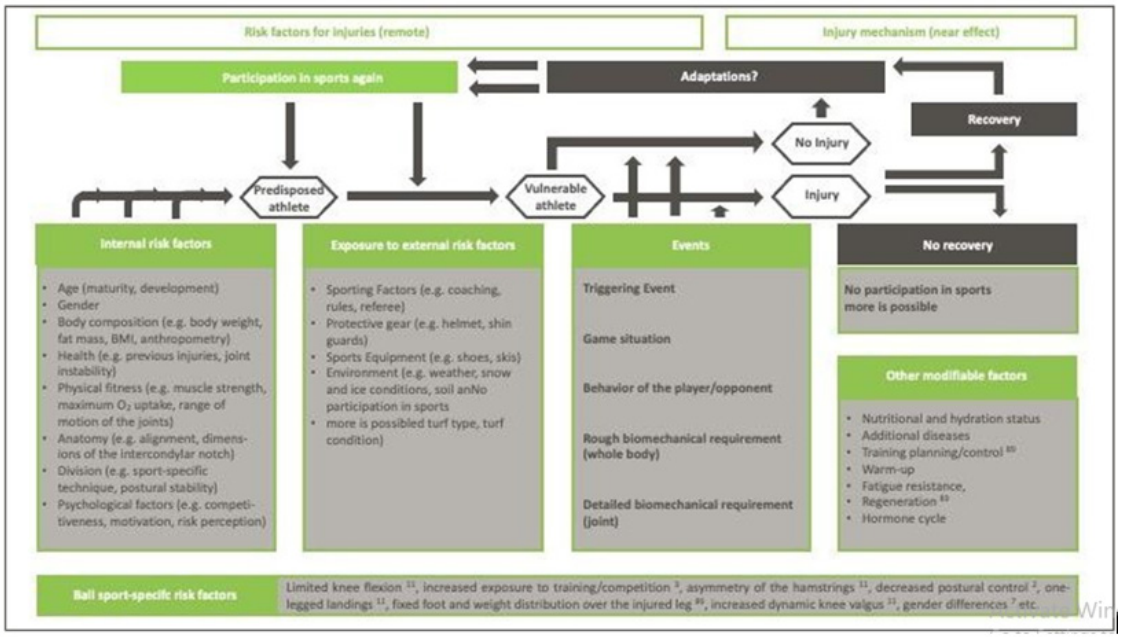

Figure 1: modified risk factor model [42].

Coordination also plays a role, which means the interaction of motor, sensory, and neuronal aspects in the so-called neuromuscular system. This connection is intended to enable dynamic balance of the joints, postural control, and correct movement execution [25]. The coordination skills are divided into seven sub-areas. They cannot be seen separately from each other because they are all involved in the execution of the movement and therefore constantly influence each other [26]. Lastly was not one form of power. Depending on the individual requirement profile, it usually occurs in mixed forms with speed, coordination, and endurance. Since the execution of the movement is controlled neuromuscular (coordination-strength interaction), it counts as a quality criterion when carrying out the strength tests below. The rating was then followed by an analysis according to individual criteria to check the suitability of the various procedures for the sporting area. For this purpose, it was categorized into indices for time and material expenditure [27] and was expanded using a price index [28, 29]. The personnel costs for complete team testing were also added. The categories could be used to check the suitability of the entire test procedure and ensure its practicability at the training facility.

For the time index, the entire assessment for a complete team should not last longer than one training session. The reference value was the actual number of athletes on a team in the respective competition. Based on the three sports, this resulted in an average of 14.7 players. Individual tests should therefore last a maximum of 5-10 minutes, otherwise the time frame of a training session would not be adhered to (Table 2). The amount of equipment should be kept as small as possible. More expensive purchases for an intervention represented an exclusion criterion for the index (EQ). Typically, a tape measure, a stopwatch, a bench/box, a ball, markers or cones were available in the sports area. Instead of the Movement Assessment Technologies (MAT) mat or the Functional Movement Screen (FMS) Test-Kit used, adhesive strips could also be used as markers and other reference points (Table 3). The price of new purchases should be kept to a minimum. Investments of up to 100 euros for a test procedure were acceptable if they were necessary. If a single purchase for a test was more expensive, it was excluded by this index. For the MAT and the FMS, both were already available before the study and could therefore be used (Table 4). It was essential for the staff index that as few testers as possible were needed for the investigations. Ideally, one person should be sufficient and if the distance is too great, an inactive volunteer could help. The exclusion criterion for a test was if more than three people were required (Table 5). The applicability of a test was checked by its validity. The literature search was used to ensure that the assessments had already been included in scientific studies or had been examined themselves. The connection to the required sports and their requirement profiles was also important. The specificity was related to the most frequently occurring injuries during training or competition.

The ratings now followed. Although no other methods could be identified and TSK was recommended by experts, its practical suitability for the planned screening should still be checked using the individual indices (Table 6). In advance of this evaluation,

a preliminary selection of test procedures for the remaining requirements (too long, expensive, a lot of staff or unspecific) was made. The focus should also be on the similarities between the sports and the movement patterns that lead to injuries. The possibility of a side-to-side comparison of the lower extremities was preferred. If a test could not guarantee this, it had to be excluded. In addition, a standardized starting position had to be considered in the examination to keep the time required to a minimum and to be able to compare the results later. Further there are many short sprint distances in all three sports, but those over 30-40 m are rather unrealistic in basketball or handball. They take place in football but are often bridged with long passes. Of course, no tests that would compare passing situations between basketball, football and handball players could be considered [30]. Some hop tests [31] would also have been suitable for use. However, they would have taken too long, and the rotational hop had the advantage compared to the forward hop test in that it resembled an injury-causing movement pattern. All strength tests mentioned had good to excellent validity [32] and high specificity. However, the original Side Bridge Endurance Test was adapted to assess for additional weakness in hip abduction and to focus on the importance of proximal stabilization in preventing lower extremity injuries [33]. As a result of the previous review, one questionnaire, two speed, three coordination and four strength tests were selected, and these will form the actual test battery. It was recommended that TSK questionnaires be included in injury prevention research. They may have the potential to identify high-risk athletes without extensive equipment [34]. Kinesiophobia refers to an irrational fear of physical exercise that results from a feeling of susceptibility to injury. In fact, this fear could lead to injury [23]. In addition, the questionnaire had proven to be a valid instrument for assessing fear of movement and injury [35]. The Modified Star Excursion Balance Test (MSEBT) had previously been cited as a reliable measure for predicting the risk of lower extremity injury. In addition, dynamic balance deficits could be identified [36].

Table 2: Time index.

1	under 1 minute
2	1-3 minutes
3	3-5 minutes
4	5-10 minutes
5	over 10 minutes

Table 3: Equipment index.

0	No equipment
1	Standard equipment
2	Additional equipment

Table 4: Price index.

0	No costs
1	1-50 Euro
2	50-100 Euro
3	More than 100 Euro

Table 5: Staff index.

1	1 Tester
2	1 Tester & 1 assistant
3	1 Tester & 2 assistants
4	More than 3 people

Table 6: Ratings of the test procedures.

Testing	ICC	Time	EQ	Material	Price	Staff
Tampa Scale of Kinesiophobia (TSK) [22]	0, 90 [48]	3	1	Questionnaire & pen	1	1
20m Sprint Test [4]	0,78-0,95	4	1	Cone, stopwatch, measuring & adhesive tape	1	2
Modified Agility T-Test [46]	0,74-1,00	4	1	Cone, stopwatch, measuring & adhesive tape	1	1
Modified Star Excursion Balance Test [40]	0,84-0,92	4	1 (2)	Measuring & adhesive tape (or MAT)	1 (3)	1

Rotational Single-Leg Hop Test [25]	0,93-0,95	4	1	Measuring & adhesive tape	0	1
Vertical Jump Test [4,72]	0,88-0,99	4	1	Measuring & adhesive tape	0	1
Vestibular Balance Test [20]	k.A.	4	0	Stopwatch	0	1
Side Bridge Endurance Test [2,57]	0,76-0,91 [30]	4	0 (2)	Stopwatch (FMS)	0 (3)	1-2
Single Leg Hamstring Bridge Test [34]	0,77-0,89	4	1 (2)	Bench or box (FMS)	0 (3)	1-2
Single Leg Rise Test [21,82]	0,66-0,94	4	1	Bench or box	0	1-2

When differences in the totals of all ranges compared to the sides were greater than 10%, the probability of a non-contact injury was increased 3.5 times [37, 38]. In addition, a 2.5-fold increased risk of injury was reported when the anterior reach was restricted by more than 4 cm [39]. The 20 m Sprint Test (20MST) was said to have good objectivity, reliability and average validity [40]. Furthermore, this speed test is unlikely to have a learning effect, it was highly valid for children and adults and the assessment was carried out using standardized tables of norms [41]. Since a critical movement pattern was being tested here [2], it seemed obvious to include this test. In conjunction with the strength test, conclusions could possibly be drawn about the muscle groups at risk. The Modified Agility T-Test (MATT) tested the requirement for multi-directional speed with different movement patterns and changes of direction [42]. The test-retest reliability of this test was 0.98 [43]. Although the modified test was carried out in the same direction and number of direction changes, the total distance was shorter [44]. In addition, this test represented a further simulation of an injury-prone pattern, stops and change of direction [2]. The Vestibular Balance Test (VBT) tested dynamic postural control under difficult conditions, which could be a cause of injuries [45]. Deficits in postural control when standing on one leg could influence the dynamics of the lower extremities. They even carried an increased risk of non- contact injuries [46]. After injuries have already occurred, the ability to balance should be restored as quickly as possible to reduce the risk of a new one [47]. The 90° Medial Rotation Hop for Distance Test (90MRHT) has been reported an excellent test-retest reliability. Medial and rotational hop tests demonstrated lower limb asymmetries rather than forward in non-injured and ACL-reconstructed participants [31] Injuries described when landing after a throw, block or header on the one hand and stops or change of direction on the other showed that they were three-dimensional movements. Therefore, unidirectional tests did not seem to be sufficient, but a combination seemed to be better [2] For the Vertical Jump Test (VJT) some prefer the two-legged test [48], others found it to be insufficiently informative [49]. The decision was therefore made to use this test because, in addition to assessing the jump height in a side-to-side comparison, it also allows an assessment of the leg axis and an isolated consideration of knee and ankle joint dynamics [11]. And it was a realistic depiction of a sport-specific situation (Figure 2).

Figure 2: Side Plank Leg Raise Test (SPLRT).

The Single Leg Rise Test (SLRT) could be important for early detection of people with poor prognosis. Additionally, the maximum number of single leg rises was a complex performance that required multiple muscle groups and coordination [50]. After injury to the ACL, impairment of dynamic balance during a single-leg squat was evident bilaterally. The deficits contralaterally were like those of the injured side. This could have an impact on physical function and a further risk of injury. Routine assessment of dynamic balance could help identify high-risk athletes [51]. The Single Leg Hamstring Bridge Test (SLHBT) was used to check the function of the hamstring muscles, injuries to which were a complex and multifactorial problem. There was a significant deficit in the values in the preseason on one side in players who subsequently sustained an ipsilateral thigh injury. Old age, previous knee injuries and medical history were further risk factors. Thus, the test could be used to identify athletes who may have been at risk of a hamstring injury [51]. For the Side Plank Leg Raise Test (SPLRT) the trunk dysfunction was associated with lower extremity injuries. Women demonstrated reduced core endurance compared to men, which has been linked to higher injury rates in women [52]. They also showed significantly reduced endurance during side plank and hip abduction. As a result, women may be comparatively predisposed to excessive movements in the hip or trunk, potentially placing them in positions that are often associated with non-contact injuries. Additionally, athletes who sustained an injury demonstrated significant weakness in hip abduction. These results highlighted the importance of proximal stabilization in the prevention of lower extremity injuries [33]. Due to the reduction in support area compared to the Side Bridge Endurance Test, the execution time requirement was reduced to half the duration specified by the authors.

In addition to the assessments listed above, the specificity about the conspicuous movement patterns and the one-legged execution were decisive for the selection of the tests, as this dominates in team sports. Sprinting was best tested by sprinting and the 20m was the lowest common denominator of the three sports. Single-leg landings were simulated through the jump assessments and could be assessed not only quantitatively but also qualitatively. Stopping and changing directions were easy to test with the MATT. For injuries that occurred while standing, it was obvious to choose a one-legged examination. The strength tests objectively represented the strength capabilities of the muscle groups most affected by injuries. They were supplemented by testing core strength and hip abductors, which had an influence on leg stability. Electronic timing was considered the gold standard in sprint testing. However, measurements by experienced examiners with a stopwatch did not show any significant differences in comparison. Therefore, manual measurement is likely to be a valid method of assessment [53]. The Limb Symmetry Index (LSI) was used to compare sides. The goal was either a reference value from previous measurements or 95 to 105% in a side-by-side comparison [54].

To ensure performance-oriented exercise, only athletes from the 1st and 2nd league for basketball, football, and handball were used as test subjects. The players also had to have at least 5 years of training experience, 3-4 training units per week and be 18-30 years old. Participation was voluntary and free of charge. Athletes with serious injuries in the last 2 years, current overuse syndromes, after-effects of recent illnesses or recent pregnancies were excluded. To obtain a reliable interpretation of the individual procedures in the test battery, a qualified, experienced group of raters with several years of professional experience was essential. Sports physiotherapists and scientists had completed extensive training and were constantly involved in the interpretation of movement sequences and sports motor skills in their daily professional activities. People without sports care activities in the last 2 years or experience with testing procedures were excluded.

Although two of these test procedures have not yet been tested in this form in studies, they appeared to be apparently valid. Otherwise, the range of all ICC values in terms of test-retest reliability was 0.68-1.00. The supposedly lowest rating was achieved by the SLRT and the MATT the highest. The classification of the ICC values, based on the 95% confidence interval, was then described [32]. Since almost all values were greater than 0.7, they were viewed as indicators of good agreement [12]. The procedure for determining the necessary number of cases was carried out based on the calculation with test-retest reliability by using ICC values from the available studies for the individual test procedures in the test battery. For this reason, with 3 raters, in view of an ICC of at least 0.7, there is a need for at least 6 (power of 80%) to 8 (power of 90%) test subjects [55]. For the optimal process of a test battery, it was an advantage if the tests were presented in advance [41]. The participants therefore took part in a meeting via video conference in advance. The procedure was presented here using video or image material. The test subjects were asked to try it out themselves in advance to familiarize themselves with it. The actual implementation of the assessments, including the measurements, took place on another day. Immediately before the test, the test subjects completed a 15-minute warm-up including sprints and changes of direction. This was followed by a 5-minute rest period during which the TSK was completed. Further checks were then completed. The exact technique was explained again before each of the tests and each athlete usually had 2 attempts in each. To ensure timely feasibility, test trials had to be dispensed with. The only exception was invalid attempts. The athletes were allowed to repeat again after a break (30 seconds or 3 minutes). If another failed attempt was made, the test would have been recorded as "unfeasible". The entire series of tests was carried out in the order listed on a day without training. The study participants were divided into two-person teams. This meant that longer breaks were avoided, and the test subjects were able to motivate each other. The collection of personal data and consent to participation took place in advance.

To prevent fatigue from multiple tests runs and thus a change in the results, one run of the test protocol was carried out and recorded on video. This also ensured objectification of the analysis by the individual raters. The evaluation took place on a different day than the implementation. A PANASONONIC "Lumix" DMC-TZ41 with 18.1 megapixels, a resolution in full HD (1920 x 1080 pixels), a sensor output of 50 images/sec, and 4x optical zoom was used for the video recordings. The raters received instructions in advance

regarding the test battery, implementation and termination criteria and the same video or image introduction as the test subjects. The allocation was randomized. The entire video recording was made available to them so that they could evaluate it independently of time and technology. The analysis should only be carried out once. It was not possible to coordinate the assessments because the people did not know each other. All test evaluations were sent to the study director and collected for later statistical processing.

Results

A total of three raters were involved in the test procedures. Eight test subjects (n=8) were selected according to the criteria listed. The gender distribution in the group of test subjects was four women and four men. The performance level appeared to be the same for all participants, apart from gender differences. The group consisted of five handball players, two soccer players and one basketball player, and of these, 2 had right leg dominance and 6 had left leg dominance. The average age was 22.63 years with a standard deviation (StD) of ± 3.78, with the youngest being 18 (minimum) and the oldest being 27 years old (maximum). The mean weight was 77.75 kg (StD ± 7.29), and the height was 177.38 cm (StD ± 6.30). The test subjects stated that they were fully capable of exercising. The athletes had achieved quite different results. The raters' comparative values seemed quite homogeneous. In single-leg tests, at least one trial per side took place. The results show that TSK three were identified with increased fear of movement. Two test subjects had an increased anterior reach greater than 4 cm (LSI of approx. 92%) in the MSEBT when compared from side to side. No one had an overall side difference of more than 10%. The sprint results were all moderate to below average compared to the reference values [56]. Half showed side differences in MATT, with LSI not reaching the 5% limit. During the VBT, no person was able to complete the test completely positively. At 90MRH, three people had a moderate deviation of more than 5%. During the VJT, two were able to reach a jump height of greater than 40 cm, with one subject showing a clear side difference (LSI of 120%). Five participants had more than 10% strength deficit during SLRT (LSI > 160% otherwise < 90%). Almost half managed the specified 22 repetitions. In comparison, five test subjects showed a 10-60% increase in strength on the dominant side during the SLHBT. At the same time, one subject had a 15% reduced ankle performance. Nevertheless, only one subject was able to complete the requirement of 30 repetitions on his dominant side. The SPLRT goal of 1 min could only be achieved by one athlete on the more pronounced left side and four others had a very clearly positive LSI (11-50% more) and two had a negative one (17- 27%) (Table 7).

Table 7: Comparisons of the assessments of the individual test subjects.

TP	TSK	MSEBT	20MST	MATT	VBT	90MRH	VJT	SLRT	SLHBT	SPLRT	!!!
1			> 3:40		N			109,09	117,39		**4**
2	N	105,24 (total)			N	105,94	120	161,54	161,90	112,62	**8**
3		92,31 (ant.)	> 3:50		N			93,10	112	129,8	**6**
4		91,89 (ant.)			N			88,89	91,67	111,01	**5**
5	N		> 3:50		N				90,91	82,79	**4**
6			> 3:50		N		91,30	85	88,89	150,05	**6**
7		106,61 (total)	> 3:50		N		91,30	86,67	125		**6**
8	N				N		92,59	85,71	120,83	78,16	**6**
!!!	**3**	**4**	**5**	**0**	**8**	**1**	**4**	**6**	**8**	**6**	

Legend: TP = test subject; !!! = sum of all abnormalities; N = no, e.g., 105.24 = LSI in %; ant. = anterior; > 3:40/3:50 sec = highest specified reference values

Competitive athletes should not show any abnormalities in the TSK [23, 34] and side differences in the LSI should not be more than 5% [55]. The specified reference values for the speed of players [57] served as orientation for sprint evaluation. The assessment of the VBT was also carried out based on the information [45] (Table 7). Shows that only one test procedure did not show any abnormalities (MATT) and none of the test subjects are likely to be without potential risk factors. The present pilot study also addressed the interrater reliability of this test battery. Therefore, all three raters (3) also rated each subject. The assessors were randomly selected from the professional groups mentioned above. Therefore, a double random model (2) was assumed. To be able to show the difference between the results of the eight test subjects, absolute agreement was required in the individual measurements. To be able to control the variability and sensitivity of the measurements of the entire test procedure, the Standard Error of Measurement (SEM) and Minimal Detectable Change (MDC) were determined. The SEM defines how large the measurement error of the assessment is and the MDC defines how much change must be present to be clinically relevant. If there was 100% agreement in ratings, Cronbach's alpha (α) was presented instead as a measure of the internal consistency of a scale. In unilateral testing, both sides are evaluated separately using the ICC (2,3). Overall, this clear order made it possible to have an unambiguous view of the validity of a test procedure. If a limit value is included in the assessment by the confidence interval, the assessment is described as "good to excellent" [32]. The measurement results of the individual test procedures and raters are all quite accurate, so this is assumed could be ensured that they were not influenced by measurement errors. The interrater reliability of the entire test battery, calculated using the mean

value of all the ICC (2,3) just listed, is 0.997 and can be classified as excellent. The MSEBT of the left anterior reach had the lowest value in this series of studies with an ICC (2,3) = 0.989. The highest had TSK, VBT Side to Side or Up and Down, SLRT on the left and SPLRT on both sides with an ICC (2,3) = 1.00. It was noticeable that the ratings overall were very close to each other.

Discussion

In general, one of the biggest hurdles for the individual assessments of this test battery was filtering the vast number of test procedures according to the previously mentioned criteria. At the same time, it was important not to lose sight of the specificity of the three sports and the criteria of the indicators for feasibility. Some tests seemed more suitable at first glance, but upon closer inspection they would have exceeded the specified scope. The determined interrater reliability regarding the TSK was classified as excellent with an ICC of 1.000. It was not clear why three people had failed the assessment. For example, one subject already had a strong history of injuries, five had suffered an injury 2 years ago and one suffered from knee pain. Despite everything, it was not known what experiences these athletes had already had with pain or how much their upbringing or their environment had influenced them. However, it seemed that from a biopsychosocial perspective there might be a not insignificant influence on this. Preparatory work by other authors [36, 38] and the adaptation to the time frame determined exactly what the execution of the posture control would look like. The MSEBT most closely corresponded to the specified criteria. The interrater reliability showed an ICC (2,3) of 0.989 (95% CI: 0.964-0.998; SEM = 0.15; MDC = 0.41) for the anterior reach on the left and 0.994 (95% CI: 0.982-0.999; SEM = 0.08; MDC = 0.21). The total range on the left was 0.998 (95% CI: 0.993-1.000; SEM = 0.08; MDC = 0.23) and on the right was 0.996 (95% CI: 0.986-0.999; SEM = 0. 15; MDC = 0.42). Overall, although it was the lowest value recorded, this also corresponded to an excellent assessment. Three test subjects had already suffered knee and ankle injuries, while one complained of knee pain. The extent to which the previous damage affected the results of the test remained unclear. On the one hand, limited mobility of the ankle joint, for example, could be responsible for this. On the other hand, a connection with reduced, one-sided trunk stability (SPLRT) could also be seen. It is therefore recommended that the corresponding connections be researched in further studies. The three sports had to be brought to a common denominator in terms of speed and agility because of the different playing field sizes. However, since long sprints or changes of direction are rarer, short sprints predominate. It was also important to take the different running directions and movements into account (specificity). In terms of validity and equipment, other tests would have been more suitable [57, 58]. However, they would not have been feasible in the time frame. The interrater reliability of the 20MST was 0.997 (95% CI: 0.955-0.999; SEM = 0.002; MDC = 0.005) and the MATT left was 0.998 (95% CI: 0.978-1.000; SEM = 0.002; MDC = 0.005) and right of 0.999 (95% CI: 0.990-1.000; SEM = 0.001; MDC = 0.003) and were both classified as excellent. The moderate to below average performance of five test subjects on the 20MST could be due to previous injury. It was noticeable that none of the female participants could meet the requirements. However, training deficits or missing content can also be responsible, or someone is simply not a counterattack player or is only used in defense (e.g., coverage specialists in handball). However, it was questionable whether the reference values [57] were set too high for this performance group. The slightly worse performance on the MATT on the left in two subjects could be related to previous injuries to the left knee and subsequent surgery. Nevertheless, one could also assume that side differences can depend on the respective playing positions. Further research is certainly needed in this regard.

The tests around functionality represented a mixture of coordination and strength. They required a certain level of skill and the necessary level of strength. What was crucial here was the specificity and being able to cover as many movement patterns as possible with just a few tests. The VBT seemed essential to be able to check standing stability at rest [45, 2]. Because if it couldn't be carried out easily, it would most likely be even less possible in the dynamics of the respective sport. In addition, an assessment in an explosive version would be quite difficult, as important details could be overlooked or a considerable amount of additional equipment would be required. Despite the lack of information about test-retest reliability in the literature, it was rated by all raters with 100% agreement (ICC (2,3) = 1.000). No test subject was able to pass this assessment completely. Further research would be recommended to find out why. From a practical perspective, one might think that the one-legged stand has not been trained in this form before. In addition to balance, the ability to orientate, differentiate and connect was also addressed. But experience has shown that this exercise produced a learning effect relatively quickly. It was questionable whether the test would have led to better results in a recovered state, e.g., before the speed assessments. 90MRH and VJT presented a good opportunity to recreate the specific one-legged landing [2]. On the one hand it is about distance with rotational impulse, e.g., a landing after physical contact and on the other hand it is about pure jump height. Both demonstrated excellent test- retest reliability. The 90MRH achieved an ICC (2,3) of 0.999 (95% CI: 0.996-1.000; SEM = 0.04; MDC = 0.13) on the left and 0.999 (95% CI: 0.998-1.000; SEM = 0.04; MDC = 0.12). on the right. The VJT showed an ICC (2,3) = 0.994 on both sides, left (95% CI: 0.980-0.999; SEM = 0.12; MDC = 0.33) and right (95% CI: 0.981-0.999; SEM = 0. 13; MDC = 0.35). Except for one test subject, no connection with leg dominance could be discovered. Nevertheless, the results could be associated with previous injuries or current pain [55]. It would be interesting to see what conclusions further studies would come to.

The selection of strength tests was easy to make with the help of the indices in favor of feasibility. The interrater reliability data researched in the test battery was as follows: SLRT ICC (2,3) left = 1.000 and right = 0.992 (95% CI: 0.975-0.999; SEM = 0.10; MDC = 0.29), SLHBT ICC(2,3) left = 0.996 (95% CI: 0.986-0.999; SEM = 0.05; MDC = 0.14) and right of 0.999 (95% CI: 0.995-1.000 ; SEM = 0.02; MDC = 0.05) and SPLRT ICC (2,3) bilateral = 1.000. The data showed such small differences that a high level of measurement accuracy can be assumed with slight variations in the speed of reaction of the individual raters. Here too we could speak of an excellent classification. The quantitative results of the tests led

to the conclusion that there were significant strength deficits for most of the test subjects. It was not possible to answer whether it was due to the lack of training content or the injury history. What was striking was that most of them managed the SLRT, but almost no one managed the SLHBT and SPLRT. This suggested weakness of the posterior relative to the anterior thigh muscles. Given the synergistic function of the hamstrings for the ACL, this could be one reason for its trauma. The weak trunk and hip muscles could also lead to a predisposition to dynamic knee valgus, which would be a predisposing factor, especially in women. And in all tests, there were clear differences in the LSI, as well as a risk factor.

The individual components of the test battery appeared to be well documented in the literature. They had high specificity and reliability and could be implemented without much effort, making them practical. As a recommendation for further research, other methods for screening risk factors could be incorporated into the test battery. But it would also be desirable to carry it out in a fatigued state using specific procedures [45]. However, any change in the modalities would result in a new assessment based on the indices and the interrater reliability would also have to be redetermined. The mean value of the ICC (2,3) was 0.997 (95% CI: 0.955-1.000). But since these raters were specialists, this would have to be checked again in the case of less experienced ones. Nevertheless, interrater reliability was an important prerequisite for comparison with other studies.

For the feasibility the indices made it possible to create a framework for a very good and practical implementation of the test battery. The test run required a time commitment of 90-120 minutes for a team of up to 15 players. In most ball sports, this corresponds to one training session. It was advisable to do it in pairs to prevent fatigue and increase extrinsic motivation. Although it would not be necessary to purchase additional equipment, it could have advantages for reproducibility. The MAT and the FMS test kit made time easier. This test battery was very easy to carry out. To simplify or speed up the process, a longer preparation phase and possible assistants would be desirable. Video analysis had proven to be an objective tool for allowing multiple raters to evaluate under the same conditions. Symptoms of fatigue could also be avoided by repeated testing for both test subjects and raters. This seemed to be a very good instrument for determining interrater reliability. However, the technology also had disadvantages, such as a limited field of vision for the camera operator, which was rather advantageous for the raters, and slight delays and blurring due to the dynamic recording process. For further studies, it would be advisable to familiarize yourself with the technology in advance or to use additional cameras. But do multiple perspectives correspond to practice with just a single rater? It seemed to be recommended for future research that the examiner and the Filmer should be two different people.

There was some risk of bias in this study. The author was both a rater and a test and study director who summarized all the results and prepared them for statistical processing. All subjects were also known directly. However, since the focus was on the quality and not the quantity of movement execution, this fact may have been neglected. The distribution of the study objects was very homogeneous. Both genders were equally represented, the performance level was consistent, and there were only minor differences in weight and height. There was only a larger range when it came to age. Nevertheless, a gender-separated or mono-sports analysis would be useful for further studies. The test battery collected an objective status of the athletes to be able to individually adapt training plans. Supplementary exercises could compensate for the problems and, in the best case, injuries could be avoided. The effectiveness of the interventions could be checked through follow-up testing. If an injury does occur, the values could be used as a guide for subsequent rehabilitation. However, since standard values were not available for all assessments, further research would be recommended. The number of subjects was too small to generalize the data.

Conclusion

In summary, it can be said that contact injuries cannot be predicted. However, this screening offers the chance to identify risk factors for indirect or non-contact injuries and then implement interventions to reduce the risk. This contributes to increasing performance and unrestricted participation in training. It was not possible to give a generally valid answer here as to which valid tests exist. As part of this test battery, the focus was on certain criteria such as time, equipment, budget, and personnel expenditure as well as sport-specific validity. The selected test procedures therefore appeared to be the most suitable to cover the spectrum of performance areas and risk factors. The inter-rater reliability of the screening was made up of the mean of the individual assessments and was assessed as excellent with an ICC (2,3) = 0.997 (95% CI: 0.955-1.000). The evaluations of the different test procedures were also rated as excellent, taking into account the confidence intervals of 95% - TSK (ICC = 1.000), MSEBT (ICC = 0.989 for anterior and 0.996 for total), 20MST (ICC = 0.997), MATT (ICC = 0.998), VBT (ICC = 1.000), 90MRH (ICC = 0.999), VJT (ICC = 0.994), SLRT (ICC = 0.992), SLHBT (ICC = 0.996) and SPLRT (ICC = 1.000). The feasibility of the test battery was assessed as very good. The standardized screening can be implemented practically by one tester with a team of up to 15 players in one unit. In most cases you can work with the equipment available. Good planning is an important prerequisite. Video analysis was a reliable technical aid. It would be questionable for future research whether the reliability would change with a larger intervention group or modification of the test battery. A larger number of participants could be achieved through a multi-center study. It would also be advisable to look at the gender and sport differences. What could a prevention program base on this look like? In any case, further research in risk management [59, 60] and to create specific reference values is recommended [61-95].

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Conflict of Interest

No Conflict of Intertest.

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