TITLE:

Assessment of Injury Risk Factors in Male Youth Soccer Players

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LEAD SUMMARY

Risk factors that may increase injury risk in male youth soccer players have been outlined previously, including: growth and maturation, movement skill, fatigue and previous injury. Practitioners should utilize suitable assessment and monitoring tools that can be used to systematically screen athletes for these risk factors to assist in the early identification of high risk athletes. The key factors for effective implementation have been reviewed in this manuscript.

INTRODUCTION

We have previously outlined common injuries in youth male soccer and a range of risk factors that may increase relative risk of injury in male youth soccer players, including: growth and maturation, movement skill, fatigue and previous injury (66). While an understanding of these factors is important, practitioners should also utilize suitable assessment and monitoring tools that can be used to systematically screen athletes for these risk factors. Therefore, this commentary will provide an evidenced based discussion of suitable assessment and monitoring strategies that are practically viable and effective in reducing injury risk.

MONITORING GROWTH AND MATURATION

Youth male soccer players display a heightened risk of sport related injuries during the year of peak height velocity (70); implementing methods to monitor the rate of growth and maturation is deemed necessary to identify this at risk population. Lloyd et al. (41) offer an extensive commentary of the range of methods available to determine maturity status and their implications for programming. It is beyond the scope of this review to discuss in great detail; however, the key points are highlighted below:

1. Skeletal age assessment may be considered the preferable method but are costly and require specialized expertise;
2. Tanner staging only provides categorical data and could be considered an unnecessarily invasive method of assessment;
3. Longitudinal tracking of growth rates provide a simple approach which may be possible in the context of a soccer academy and could be considered the

most important aspect to monitor for identifying growth spurts associated with periods of increased injury risk (70).

4. In the absence of longitudinal data, predictive equations using age and anthropometric variables can provide an estimate of maturity. The predictive equations of Mirwald et al. (46) have recently been adapted to provide a simpler and more accurate equation, which only requires measures of age and standing height (47).

Thus, longitudinal tracking of growth rates and periodic estimations of somatic maturity (approx. every three months) allow practitioners to identify periods of accelerated growth indicative of increased injury risk in male youth soccer players. Also, the above measures should be considered alongside an assessment of training age and technical competency to ensure appropriate adjustments are made to individual training prescription throughout each stage of growth and maturation (41).

ASSESSMENT OF MOVEMENT SKILL

Within the available literature, a range of movement skill assessments have been proposed for children, in particular, the Movement-ABC 2 (25), Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-BOT-2) (5) and more recently the coordinative motor skills scale (CMSS) (1) (see Cools et al. (11) for a detailed review). It should be noted that these assessments have been primarily used with young children to identify developmental coordination disorders (24, 31). These methods may not be reflective of youth males engaged in competitive sport, in particular those involved in elite level youth soccer. Therefore, it would appear that the availability of valid and reliable assessments of movement skill for this population is somewhat limited.

An alternative movement assessment is the functional movement screen (FMS) (10). Utilized frequently in professional male soccer (43), this seven station assessment includes a range of mobility and stability based tasks. This modality has shown acceptable reliability (57) and was originally intended for determining a foundational movement baseline (10). More recently, available literature has assessed the relationship between movement performance and injury identifying a total reporting score of <14 is a positive predictor of injury (8, 34, 40, 54). However, none of these studies assessed male youth soccer players. Also, recent reports have highlighted limitations in solely utilizing the total score due to low internal consistency in FMS sum scores (33, 36, 74). Thus, greater attention should be directed to the scores of each individual test rather than the composite score to identify specific movement patterns which demonstrate reductions in movement quality. Practitioners should also be cautious when interpreting scores on mobility based tests without analyzing the quality of the movement, as high scores may be achieved in the presence of hypermobility which may be a risk factor for certain injuries (58). Both inter and intra-rater reliability has been established in youth populations (73), but to the knowledge of the authors no research has been conducted which a) validates FMS total score as an injury predictor or b) reports inter-session reliability. Therefore, practitioners should consider the above limitations when screening their young athletes.

A final point of consideration for practitioners using the FMS (and those of similar screening protocols) is that the tests are primarily comprised of static tasks unlike the dynamic nature of soccer. This is confounded by reports that highlight poor relationships with dynamic movements of athletic performance (62). However, in youth male soccer players conflicting evidence is present. Significant correlations (r = 0.4-0.7) are reported between the FMS total score, deep overhead squat, in-line lunge, active straight leg raise and rotary stability tests and various measures of jump and agility performance (42). Additionally, in-line lunge performance explained the greatest variance in reactive strength index (R^2 = 47%) and agility cut (R^2 = 38%) performances, which are both dynamic measures in nature. Therefore, in youth soccer players, variation in physical performance could partly be explained by functional movement quality; however, this requires further investigation due to the paucity of empirical research.

Skill proficiency is often based on the determination of sports specific constructs involving a range of ball skills (15). This determination may not be appropriate for injury risk identification since these skills are not reflective of positions that perform high risk maneuvers involving rapid decelerations and high eccentric forces (e.g. jumping and landing tasks). To screen an athlete's level of skill and injury risk during jumping and landing tasks, a range of time efficient, non-invasive methods have recently been developed (49, 50, 61). Such assessments provide '*coach friendly'* diagnostic tools which have been reported to correlate significantly with more sophisticated laboratory techniques (50, 61). Examples include a tuck jump assessment (49), the Landing Error Scoring System (L.E.S.S) (61), and a predictive nomogram (50). These methods focus on mechanisms of injury which relate to knee injuries (more specifically the anterior cruciate ligament [ACL]) and can assist in the early identification of high risk athletes (50). Such injuries occur frequently in youth soccer, in addition to other common knee injuries including medial collateral ligament sprains (39, 65). Practitioners should also consider other diagnostic tools to assess a range of movement deficiencies for other prevalent injuries including ankle sprains and hamstring strains (65). Examples of assessments which have been able to predict such injuries include single leg jumping and landing (20), dynamic balance tasks (64), and eccentric hamstring strength (20, 38). Practitioners should be encouraged to investigate the mechanisms of frequently occurring injuries and utilize assessments to detect functional deficits which may increase injury risk. Selecting diagnostic tools that have reported acceptable reliability is also critical to ensure accuracy of interpretation for test re-test screening following targeted interventions. . Using available literature, Table 1 provides a sample movement skills test that could be used to assess lower extremity neuromuscular control for a youth male soccer player.

**********_**Table 1. Sample movement skill assessment table near here**_*************

FATIGUE

Methods for Assessing Training Load

Biochemical monitoring of training stress and recovery often involves the use of invasive protocols and costly equipment to measure changes in markers such as salivery testosterone, cortisol and IgA (45, 52). Monitoring time motion data and the residual fatigue of training (for example using heart rate telemetry) have distinct limitations too, such as day to day variation (71) and inaccuracies due to varied exercise duration, hydration and training status, and competition anxiety (37). In the assessment of youth male soccer players, heart rate measures used to determine player recovery status were not strongly associated with performance decrements. This leads to questioning their use for the determination of functional overeaching in youth soccer players (6). When considering which monitoring approach to implement, an awareness of the validity and variation present within each measure is essential to ensure accurate and reliable data is obtained. Hill-Hass et al. (26) investigated the variability in a range of physiological parameters, perceptual responses and time-motion profiles during small sided games played by adolescent male soccer players. Typical error of estimates (%) were reported for a range of variables, with heart rate responses (<5%) and session rate of perceived exertion (between 1 and 2 units) demonstrating low variability, while blood lactate variability was high (range 16-34%). Although total distance covered at lower movement speeds displayed acceptable values (<5%), higher movement speeds indiciative of the intensities of match play (>8 km/h) had greater variability. Also, recent reports have confirmed high variance between GPS units when monitoring time-motion analysis, with some units measuring two to six times more acceleration / deceleration occurences than others (7). Cumulatively, due to feasibility, cost effectiveness and time efficiency, it is recommended that approaches for monitoring training load should focus on easy to implement tools which are valid and reliable.

In addition to the measurement error associated with monitoring time-motion data, of particular importance for practitioners when considering associations with injury is the differential between the quantification of external load (distance covered, number of accelerations / decelerations) and internal load (physiological load experienced by the player). For example, a squad of players may be exposed to the same external load, however, individual physiological responses may be markedly different (3) potentially increasing a player's injury risk. Available data shows greater volumes of high velocity running are associated with soft tissue injuries in adult males (19), and in team sport athletes cumulative weekly loads (specifically three-weekly loads) are indicative of greater injury risk (9). Therefore, while monitoring such markers may be useful, purely analyzing game related data may be over-simplistic and coaches are advised to consider the internal load experienced by each player. These recommendations are supported by Hill-Hass et al. (27) who analyzed the acute physiological and time motion characteristics of three different small sided game formats (2 vs. 2, 4 vs. 4, and 6 vs. 6) using the same pitch size. The authors reported that the physiological load (measured via blood lactate, HR, and RPE) was greatest in the 2 vs. 2

player format, despite GPS data demonstrating that players completed lower total distances at the variety of movement speeds. Thus, approaches which monitor internal training load maybe more appropriate.

Traditional field-based approaches that monitor internal training load have utilized training impulse (TRIMP) measured from the average heart rate multiplied by the session duration. However, this method does not reflect the intermittent nature of soccer match play due to the averaging of heart rate and is thus inappropriate (59). An alternative approach is to use session rate of perceived exertion. The athletes' rate of perceived exertion (using an adapted Borg Scale see table 2) is assessed 30 minutes following the completion of the training session and mutliplied by the value of the session duration (in minutes) (16). This method can be adapted for resistance training by multiplying the number of repititions performed by the session rate of perceived exertion. An example to outline training load monitoring of a standard soccer week using these methods has been provided in table 3. Such approaches have been used in elite male youth soccer players with multinominal regression demonstrating that physical stress was related to both injury and illness (OR 1.01 – 2.59) (4). Specifically, for young players it is important to be educated on how to use the rating scale and how to interpret questions such as *"how hard was the session?* to ensure the accuracy of the data collected. Also, ensuring a consistent time frame between the end of a session (or game) and the time of rating is essential.

**************Table 2. Borg RPE Scale near here*************************

**************Table 3. Training Load Monitoring sheet near here***************

Monitoring neuromuscular fatigue to determine state of recovery and readiness to play

Neuromuscular fatigue is commonly measured via acute and chronic reductions in performance following a bout of exercise (13). Specifically, the inclusion of functionally relevant, dynamic movements with an inherent stretch shortening cycle (SSC) component may provide a suitable assessment strategy (35, 53), as these will incorporate the mechanical, metabolic and neural elements of fatigue (53). A measure commonly used is the assessment of jump height during a countermovement jump (CMJ) (67). It has been suggested that reductions in CMJ may provide an early indication of overreaching (72); however, the sensitivity of this approach may not be sufficient to identify deficits (12). This is supported by the reported effects of soccer-specific fatigue on jump performance (measured during a squat jump, CMJ and drop jump) in male youth soccer players (55). Decrements in jump height were present during all tasks, however, impact forces during the drop jump were the only landing force variables to show a significant change in response to fatigue. Thus, while reductions in CMJ height likely resulting from muscular fatigue were present, increased impact forces and skeletal loading associated with decrements in DJ performance might be of greater relevance for identifying injury risk. This highlights that practitioners should apply caution when just measuring muscle forces for monitoring purposes, assuming that neuromuscular capability has returned to pre-fatigue levels. Confounding this, following a fatiguing eccentric protocol, force production returned to baseline post 48 hours, whereas, electromechanical delay (EMD) was still comprised post 96 hours (28). Changes in leg stiffness during a maximal hopping task have also been reported in youth male players in response to fatigue due to reductions in pre-planned muscle feed-forward activity (56). Therefore, muscular force production and neuromuscular feed-forward and feedback mechanisms exhibit differential responses to fatigue and are separate risk factors. Such decrements have been associated with reductions in joint stability and increased injury risk due to greater stress placed on soft tissue structures (30, 60). However, individualized responses were noted (56); practitioners are encouraged to monitor the training response of each player to accurately quantify their relative risk of injury. While these methods provide valuable information regarding acute responses to fatigue, practitioners should also consider the effects of accumulated fatigue that will occur throughout a soccer season, of which there is currently a paucity of research available.

Aside from neuromuscular responses, the athlete's perception of fatigue is also an important aspect to consider, since perceptual measures are sensitive in detecting fatigue (44). Using a psychological questionnaire (table 4), players rate their state of well-being, with significant reductions in total score following competition indicative of greater levels of perceptual fatigue. Due to the fact that injury and illness appear to be related to the balance between stress and recovery (4), monitoring of psychosocial stress-recovery balance may be warranted. A method to quantify this is the Recovery Stress Questionnaire for Athletes (RESTQ-Sport). This questionnaire has recently been used with elite male youth soccer players to determine psychosocial stress across a period of two-seasons, and was associated with the occurrence of illness (OR 0.56 – 2.27) (4).

PREVIOUS INJURY

Assessment and Identification

A common method for investigating previous injuries experienced by a player is through the use of retrospective analysis. This approach relies on the individual's ability to recall their own injury history and may lead to recall bias which can occur with both long and short term retrospective reporting (32). Recall accuracy declines as the level of detail requested increases, i.e. exact number of injuries, body region and diagnosis of each injury sustained is reduced, whereas, the injury occurrence and location is more accurate (18). Due to their stage of learning, this factor may be further confounded in youth athletes. An alternative approach is a prospective reporting system, and an example form has been provided in table 4. Further guidelines for incidence reporting have been provided by the FIFA Medical Assessment and Research Centre (F-Marc) (17). Specific recommendations for practitioners indicate that the number of games and training sessions should be documented for each player, and caution should be applied in reporting injuries per position due to frequent rotations (32). This approach may be useful if used in conjunction with tests to measure functional deficits and identify players who may be at a heightened risk of injury. However, in the practical setting of a football academy, the use of prospective analysis may not always be possible due to the frequency of registering new players and transfers between clubs. Thus, alternative systems are needed which are child friendly, time and cost efficient, and provide suitable information as to a players injury history. To date, a validated questionnaire that can accurately identify previous injury history is currently unavailable within the literature. Therefore, practitioners are encouraged to develop a simple document that is child appropriate (see figure 1 for an example) and used in conjunction with a professionally led medical assessment of musculoskeletal function and movement quality.

***************Table 4. Prospective Injury Incidence form near here*****************

***********Figure 1. Child friendly retrospective injury reporting system near here******

Developing a Return to Play Criteria

Classifying an appropriate level of function assessed via rehabilitation constructs (pain, muscle strength, joint stability), movement competency and performance capacity is a critical component in the determination of an appropriate time-point for an athlete to return to play. Players that return to competitive activities too soon after injury will subsequently heighten their risk of re-injury (23). In an attempt to provide clear return to play guidelines a recent investigation by Haines et al. (22) utilized the Delphi method to identify a set of criteria from which to evaluate the suitability of assessment tools for previously injured athletes. This method has been commonly applied within available literature to validate the use of assessment tools (21, 68). Following three rounds of questionnaires, a consensus decision was made confirming a physical performance assessment checklist for prospective test batteries to be used in preparation for returning to sport following lower extremity injury (see table 5). The agreed constructs include a range of assessments to measure: stability, power, neuromuscular control, coordination, pain, movement, balance, and psychological factors (22). For further examples and guidelines of targeting deficits before return to sport see (48).

*************Table 5. Return to Play Checklist Somewhere near here*****************

SUMMARY

Individuals working with youth athletes, and in particular, male youth soccer players, need to consider effective strategies to implement a range of assessment and monitoring tools which assist in the identification of a players relative level of injury risk. The key factors for effective implementation have been reviewed in this manuscript and are summarized below:

1. When monitoring growth and maturation of players, practitioners are advised to include a range of assessment tools (tracking growth curves and predictions of APHV) to increase their accuracy

2. Qualifying a player's level of movement skill should involve tasks which challenge their level of neuromuscular control in a range of tasks which identify deficits associated to the mechanisms of frequently occurring injuries
3. Due to the associated risk of injury following acute and cumulative fatigue, methods to monitor training load, and a players state of neuromuscular readiness should be implemented to ensure they are able to meet the demands of competition
4. Previous injury should be recorded using methods that are child friendly, time and cost efficient, however, practitioners should be aware of recall inaccuracies
5. Developing an appropriate return to play criteria with specified rehabilitation constructs and physical performance capacities is recommended to reduce the risk of re-injury

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