MINI REVIEW: ASSESSING TECHNICAL SKILLS IN YOUTH ATHLETES USING SPORTS BIOMECHANICAL METHODS

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Since technical skills are suggested to play a crucial role in talent identification and development (TID) programs, sports biomechanical assessment methods could gain in importance within this field. This systematic mini review provides a brief overview of the biomechanical approaches used so far to assess technical skills and the respective findings in the context of TID. Our results show that few studies have used biomechanical approaches to identify or develop talented young athletes but those doing so found promising results. On the basis of those studies and given the advancements in technologies, we discuss possible obstacles and the potential of biomechanical assessment methods for motion and technique analysis in the context of talent research.

KEYWORDS: technical skills, youth sports, athletic performance, biomechanics.

INTRODUCTION: In the last few decades, an increasing number of TID programs have been installed by professional sports clubs, national sport associations and commercial agencies all over the world. These TID programs are unified by their goal of identifying talented young athletes as early as possible to lay the foundation for superior senior performance and long term success (e.g., Vaeyens, Güllich, Warr, & Philippaerts, 2009). Previous scientific research has developed 'talent' as a multidimensional, individual and dynamic concept (e.g., Baker, Wattie, & Schorer, 2019) that is influenced by differences in maturation and growth as well as different learning rates (e.g., Silva et al., 2010). The multidimensional concept of 'talent', as it relates to high level performance, includes a range of psychological, perceptual, cognitive, tactical and technical skills. Of those, technical skills seem to play a particularly important role as highly specialized and demanding proficiencies are required in many sports already at very young ages (Glazier, 2017). Thus, assessing and evaluating these technical skills is considered a crucial task for researchers and particularly practitioners in TID.
For this, scientists and practitioners may trust their own expertise and experience during observations (i.e., qualitative analysis) and/or they may apply biomechanical approaches to measure variables and parameters of technique (i.e., quantitative analysis) (Lees, 2002). Most studies on technical skills appear to follow an 'outcome-related' approach of measuring the movement's outcome (e.g. number of hits in a target kicking task) instead of the movement itself (e.g. kinematic analysis of joint angles during a target kicking task) (e.g. Guimarães et al., 2019). Although sports biomechanics offers a great variety of systems and tools for motion and technique analysis, it is unclear how this can be applied in TID programs. For that reason, this review aims to evaluate the sports biomechanical assessment approaches applied in TID research.

METHODS: Electronic searches were conducted in PubMed, Web of Knowledge, SPORTdiscus, SURF and Scopus. Only studies with a focus on TID were included. As such, studies were required to analyze assessments methods of sport-specific technical skills in pre-adult athletes (≤18 years of age) and examine the methods' capability to discriminate groups of different skill/performance levels, explain past performance and/or predict future performance. Search terms covered the areas of sport (i.e., 'sport* OR' in combination with various sports), technical skills assessment (i.e., 'techni* AND test* OR measur* OR examin* OR assess* OR evaluat*'), skill/performance level (i.e., 'aptitud* OR talent* OR abilit* OR expert* OR gift* OR endowment OR excellen* OR success* OR perform* OR development OR identification'), and athlete age (i.e., 'child* OR adolescen* OR boy* OR girl* OR youth* OR teen* OR young* OR puberty OR kid* OR junior* OR cadet* OR pupil* OR teen*'). After deleting duplicates, results were screened for relevance based on titles and abstracts or the full-text article when necessary. In addition, the reference list of relevant studies were checked for potential studies. Finally, included articles were analyzed regarding their biomechanical assessment method and the respective findings.

RESULTS: The electronic searches resulted in 8808 studies and the subsequent processing ultimately led to four studies applying biomechanical assessment methods in the context of TID. Study details are presented in Table 1.

Table 1: Literature on biomechanical approaches in talent identification and development

Study	Participants (skill/performance level; sport; age)	Analyzed movement and measurement system	Analyzed (biomechanical) variables	Outcomes
Di Cagno et al. (2008)	Eight elite and 17 sub-elite; rhythmic gymnastics; 14.7 ± 2.2 years	Split leap with leg stretched, split leap with ring, split leap with back bend of the trunk Optojump[1]	Ground contact time; flight time	No statistically significant differences between skill/performance levels
Re, Correa, and Bohme (2010)	Seven elite and seven non-elite; indoor soccer; 16.0 - 17.9 years	Undefined target kick, defined target kick (diameter: 1 m; height: 1m; distance: 10 m) Video analysis with ARIEL[2]; speed analysis with radar gun[3]	Time for contact; movement amplitude; foot peak velocity; post peak velocity time; contact velocity; ball velocity	Undefined target kick: higher time for contact, higher post peak velocity for elite players ($p \leq 0.05$) Defined target kick: higher ball velocity, higher time for contact for elite players ($p \leq 0.05$)
Zago et al. (2016)	Ten sub-elite; soccer; 12.6 ± 0.37 years	Slalom dribbling 3D optoelectronic motion analysis[4] with whole-body marker-set	3D center of mass' path; 3D joint angles for hip and knee considering pelvis; thigh and leg anatomical frames; stride length; stride cadence; foot-ball contacts	Higher foot-ball cadence, lower mediolateral and vertical center of mass range of motion, higher right stride cadence, lower hip and knee flexion range of motions in faster players ($p < 0.05$)
Saavedra, Escalante, and Rodriguez (2010)	133 elite; swimming; 12.1 ± 0.6 years	Fastest swimming stroke during 50m all-out swim Video analysis (sagittal and frontal) by coach	start, approach, pull-out, turn, and finish velocity; stroke rate; stroke length; swimming index	Weak to moderate (R_p = 0.25-0.32) and moderate to strong (R_p = 0.37-0.60) partial correlations for male and females, respectively

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Di Cagno et al. (2008) evaluated the leaping abilities of rhythmic gymnasts. They found no significant differences for both ground contact time and flight time when comparing elite (international level) with sub-elite (national level) gymnasts, possibly an effect of the high technical level of both groups and important factors such as technical skill and flexibility not being considered (Di Cagno et al., 2008).

Re, Correa, and Bohme (2010) assessed indoor soccer players' leg kinematics during both an undefined and defined target kick in order to check for differences between elite (national level) and non-elite (school level) players. Kinematic parameters were calculated for the period between beginning of descending swing and the foot ball contact. Additionally, maximum ball speed was measured with a radar gun. For the defined target kick, the results showed a higher ball velocity for elite compared to non-elite players while there were no differences for the undefined target kick. Furthermore, the elite players showed a significantly higher value in the time for contact variable in both kicks ($p \leq 0.05$) and in the post peak velocity in the undefined target kick ($p \leq 0.05$). All other measurements were not significant, but the elite players showed higher averages supported by small to large effect sizes (Cohen's *d* = 0.06-0.95). In summary, elite players seem to have faster and longer kicking motions leading to higher ball speeds and they can maintain that speed better in tasks with higher precision pressure.

Zago et al. (2016) examined dribbling skills in sub-elite soccer players by conducting a 3D motion analysis during a slalom dribbling test. They aimed to identify differences in the kinematic data from faster and slower players. In their results, the authors did not try to discriminate players from different overall skill/performance levels but looked at differences in the motions of players with slower and faster dribbling times. They found differences for the foot-ball cadence (higher in faster players), the mediolateral and vertical center of mass range of motion (lower in faster players), the right stride cadence (higher in faster players) as well as the hip and the knee flexion range of motions (lower in faster players). That is, the faster players show a lowered center of mass and with that body posture, they touched the ball more often in a given time, and they demonstrated a more efficient and more stable dribbling motion in an optimized path closer to the cones.

Finally, Saavedra, Escalante, and Rodriguez (2010) had swimmers undertake a battery of tests (background and training status, anthropometrics, general and specific fitness tests, technical analysis) to include this data in a multivariate performance analysis. The technical analysis of their fastest stroke comprised both a qualitative and a semi-quantitative element. With their multivariate analysis, the authors aimed to explain swimming performance. Their results show that "most selected variables pertain to the anthropometric (particularly in males), specific fitness, and technical domains (particularly in females), outstanding chronological age and aerobic and speed endurance" (Saavedra et al., 2010). Of the technical variables, most showed a weak to moderate partial correlation with performance.

DISCUSSION: The aim of this mini review was to provide an overview of studies applying sport biomechanical approaches in TID contexts. The exemplary studies presented above demonstrate the wide range of applications of biomechanical assessment methods.

Despite not all studies finding significant results for the biomechanical analysis of movements and techniques, they demonstrate the possibility of assessing technical skills with a focus on the process of moving the body, that is the motion or technique itself, as opposed to assessing the technique indirectly following an outcome-related focus. While previous research has shown the assessment of sport-specific technical skills is capable to discriminate groups of different skill/performance levels, explain past performance and/or predict future performance, focussing on the movement technique appears worthwhile as biomechanical approaches may present data and movement patterns that the human senses (primarily the eyes) cannot perceive in the first instance or that are not realized focussing on the outcome.

The technique-related focus is supported by Glazier (2017), emphasizing the crucial roles of both control (i.e., absolute motion of a single body segment) and coordination (i.e., relative motion of body segments) in the execution and the analysis of movements. That is, time-discrete kinematic variables could be used to identify associations with certain outcome variables. For example, data from a specific leg motion during a soccer kick could be combined with the ball speed, this way linking both the process (i.e., technique, technical skills) and the outcome. This reflects the crucial goal in practice of setting a movement goal or outcome (e.g., certain ball speed or spin) and the identification of respective movement solutions that can be quantified. This could be helpful for TID purposes, using specific skill levels for different performance or 'talent' levels.

Another potential advantage of biomechanical approaches is an objective measurement compared to the rather subjective evaluation by coaches. Ideally, this should not be thought of as an "either-or" but rather as a "both-and", as coaches or scouts should combine the objective motion analysis data combined with the subjective evaluation based on their extensive experience and expertise.

In addition, the potential of biomechanical assessment methods may increase further due to the rise of innovative and steadily improving data collection and analysis tools. These types of technological advances will help reduce the high organizational and preparational efforts of motion analysis that may have been an obstacle in the past. Here, markerless motion analysis

systems or inertial measurement units (IMUs) are examples of improving technology for motion analysis that allows for more representative and technique-focused assessments while reducing the experimental efforts.
Finally, biomechanical assessment of technical skills could be combined with perception research as previous research has suggested perception plays an important role in the execution of technical skills (e.g., Mann, Williams, Ward, & Janelle, 2007). Thus, the combination of perception and action would increase a method's ecological validity and representativeness leading to improved and more valid knowledge.

CONCLUSION: Our results provide first steps towards a biomechanical assessment of motions and accordingly technical skills as an integral part of comprehensive, multidimensional and longitudinal approaches within TID contexts. Despite a host of unique challenges, the studies analyzed in this review show that biomechanical motion analysis and the respective technological methods and tools could help to extend our understanding of TID as they were able to discriminate groups of different skill/performance levels and explain past performance. This is particularly crucial given the technological advancements in sports biomechanics potentially leading to reduced preparational and processing efforts. In addition, once developed and validated, biomechanical methods in TID could be used for the evaluation of other, in terms of organization and data processing demands less effortful assessment methods (e.g., questionnaires or observation sheets). In the end, this research will be useful for both scientists and coaches in TID as it improves our understanding of the value of technical skills and ultimately improves the quality of TID decision making.

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